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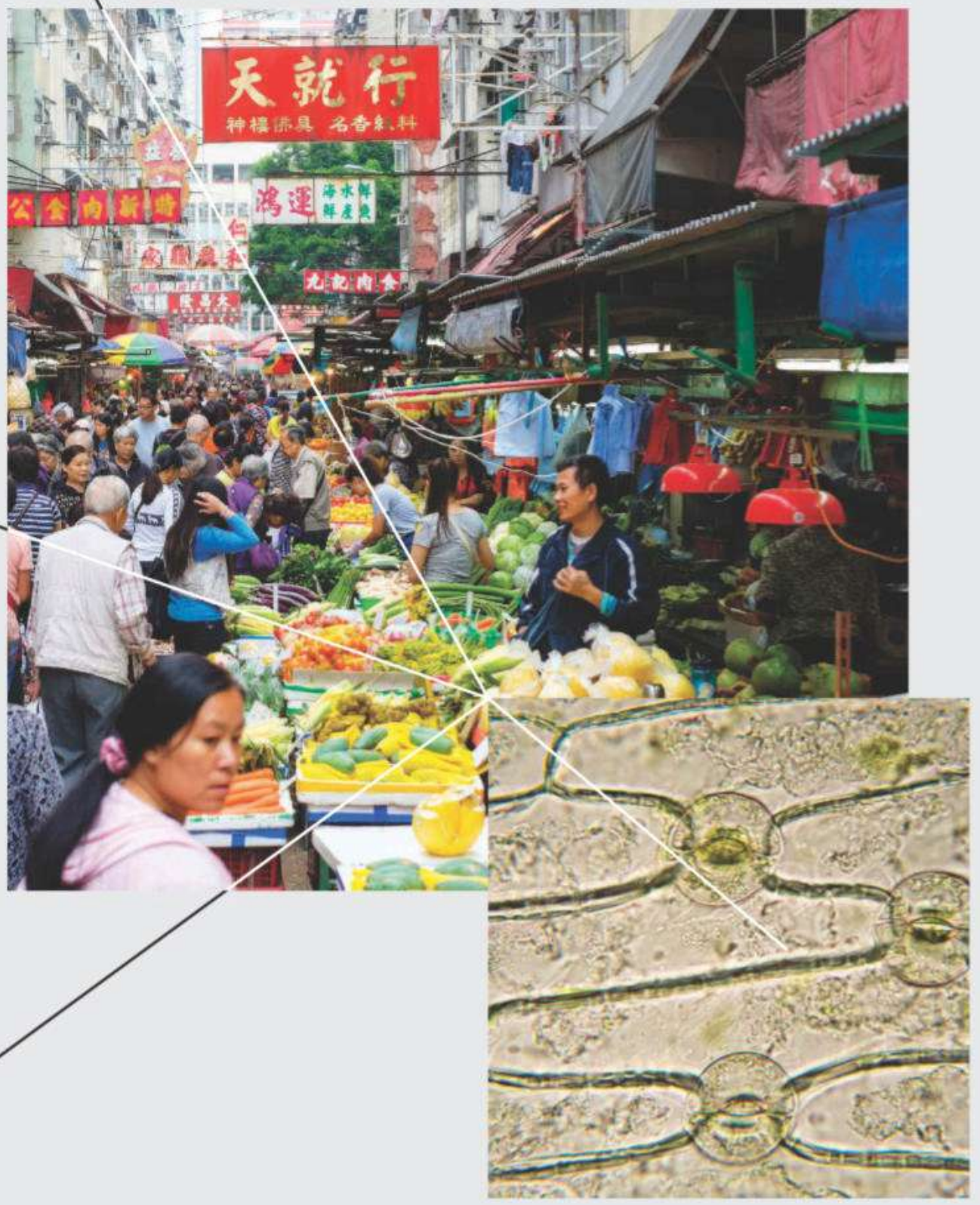

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NS Live

DNA detective

Hear presenter, author and geneticist Turi King discuss the use of DNA in genealogy and forensics at New Scientist Live on 12 October at London's ExCeL Centre. Find out how the boom in genetic testing for people's ancestry has created databases that allow us to answer previously impossible questions. You can also tune in to the talk online.

newscientist.com/nslmag

Tour

Mysteries of the universe: Cheshire, UK

Spend a weekend with some of the brightest minds in science on an excursion to the UNESCO World Heritage Site Jodrell Bank and its iconic Lovell Telescope. This getaway features lectures given by astronomy journalist Stuart Clark and others, spanning from the big bang through to the James Webb Space Telescope. This three-day tour starts on 30 August and costs £959.

newscientist.com/tours

Podcast

Weekly

The team digs into why scientific advice on alcohol consumption is so confusing. Hear about progress towards creating the heaviest chemical element ever in the lab. Plus, some unfortunate news about so-called green plastic. The podcast also takes a deep dive 5000 metres under the Pacific Ocean to learn about strange, potato-sized metallic rocks that may be producing oxygen.

newscientist.com/nspod

SHUTTERSTOCK/FELIPE CAPARROS

Family tree Find out how genealogy info helps forensic scientists

THE TRUSTEES OF THE NATURAL HISTORY MUSEUM, LONDON

Listening in The Natural History Museum's new bioacoustic garden

Video

Urban ecosystem

London's Natural History Museum has opened its revamped urban garden to the public. The 2-hectare site hosts 25 sensors gathering environmental DNA and acoustic data to help understand and protect urban nature. "We monitor sounds produced by birds or grasshoppers, but sometimes foxes come and chew the cables," says acoustic biologist Ed Baker.

youtube.com/newscientist

Newsletter

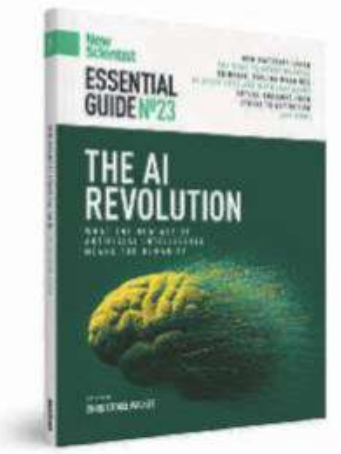
Health Check

Health reporter Grace Wade looks back on *New Scientist*'s recent special issue on exercise and considers the psychological tricks you can use to fall in love with working out. Following the recent global tech outage, she also scours the archive to look at the health consequences of tech failures in hospitals.

newscientist.com/healthcheck

Podcast

"There's something very special about these rocks that may be essential to ecosystems"



Essential guide

Tools such as ChatGPT have put artificial intelligence on front pages around the world. So why has AI leapt forwards so suddenly? How can generative AI tools help you? And will this tech lead to human extinction? Get the lowdown on all this and more in our new *Essential Guide*, on sale now.

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Professor in Experimental Psychology, University of Sussex

George Musser
Contributing Editor, Scientific American Magazine

The straight dope

Performance-enhancing drugs aren't the only source of sport inequality

ANOTHER Olympics, another battle to catch the dopers (see page 12). But why do we get so hung up on the use of performance-enhancing drugs anyway?

There are many reasons to combat them. One is that sport should be, well, sporting. People tune in to see the best of the best clash, and we like to feel there is a level playing field.

When it comes to stopping athletes gaining an unfair advantage, it makes sense to target doping. There are also health reasons for cracking down, with concerns over the long-term abuse of substances such as anabolic steroids.

But sport is rife with inequalities that we don't always think about. A nation's Olympic success correlates with two big factors: the size of its population and its GDP. In swimming, for example, bodily features, such as hypermobile knees and ankles paired with big feet and hands, can help people like British multi-medallist Adam Peaty go faster. A nation is more likely to find someone like him if they have a larger population to choose from.

"Odds are stacked in other ways too: Olympic success correlates with population size and GDP"

Meanwhile, richer nations can afford to pay athletes to concentrate on their sport, as well as supply the best diet, equipment and coaches. The result is that the big, high-income countries tend to get more medals. That isn't cheating, but it is unfair.

This inequity feeds back into the doping issue, as people from wealthier countries can more easily afford the latest body-boosting substances, so doping exaggerates the advantages they already have. This also means plans for an Enhanced Games in 2025 – in which all athletes could openly use drugs to push their bodies to their limits – wouldn't solve anything. Aside from potential health risks, it would just cement the wealth-related imbalance.

We like to think that sporting prowess is all down to talent and determination, but when viewed objectively the odds are already stacked. We have become fixated on doping because it is measurable and the fight against it feels scientific, yet even if we eliminate it, we won't get rid of inequality in sport. ▮

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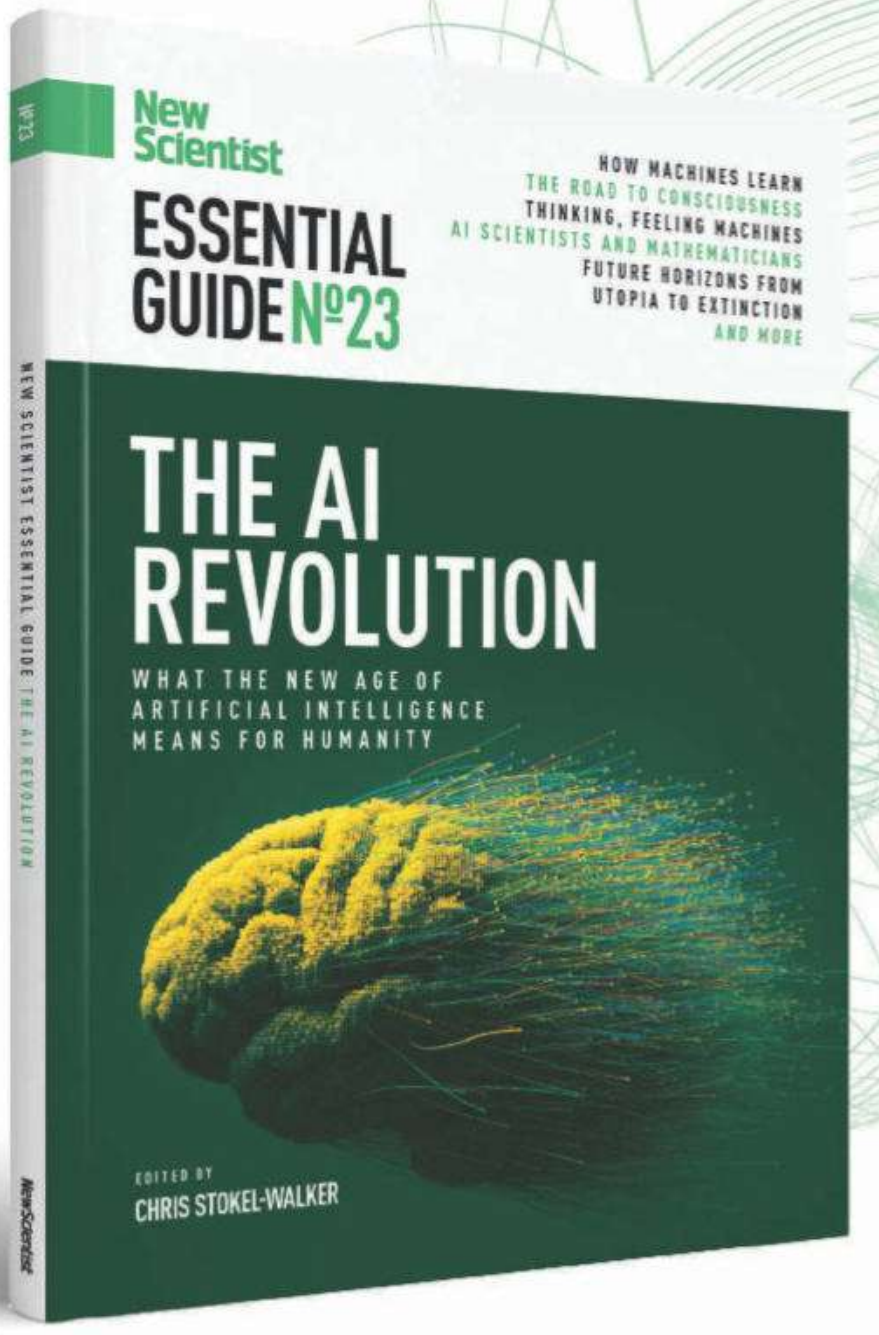

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Nº23 The AI Revolution

What the new age of artificial intelligence means for humanity.

AI has long been considered tomorrow's technology. But in November 2022 the release of ChatGPT ushered in the age of generative AI. These powerful and creative tools are transforming everything we thought we knew about the technology's capabilities and how it works. So why has artificial intelligence suddenly leapt forward? How can generative AI tools help you? And will AIs lead to human extinction? Find out how AI is set to disrupt societies and economies in this 23rd Essential Guide. Available online or at your local newsstand.

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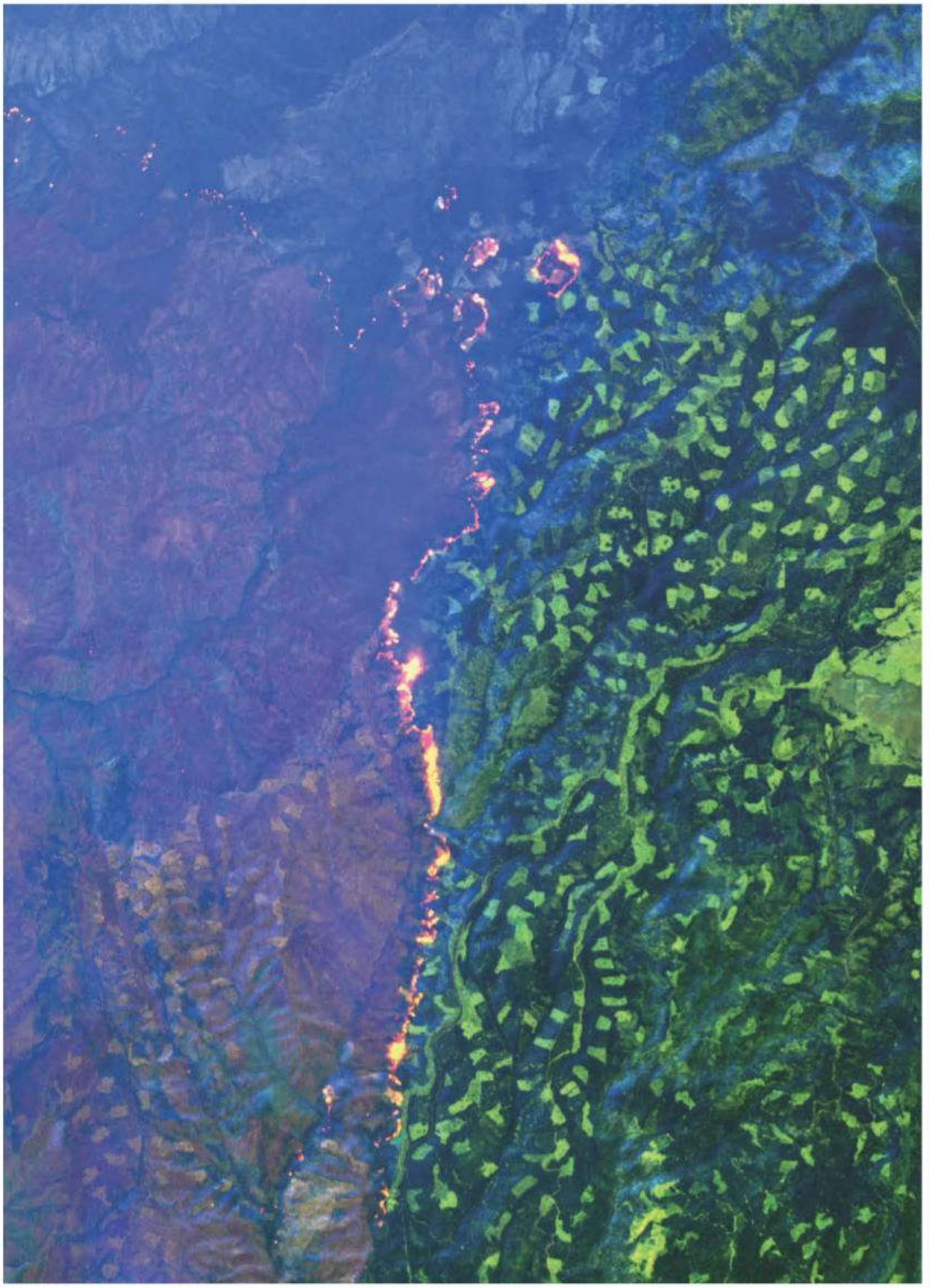


EUROPEAN UNION, COPERNICUS SENTINEL-2

Environment

Caught in the line of fire

This searing image reveals a fire front in Butte county, California, captured by the Copernicus Sentinel-2 satellite. Infrared light from the blaze penetrated the smoke and was picked up by the satellite's sensors, producing this shot. Several counties in the northern part of the state have been battling fires and, as *New Scientist* went to press, these had torn through more than 150,000 hectares, an area bigger than Los Angeles.

Palaeontology

Oldest rocks reveal bizarre cells

Fossils from up to 3.8 billion years ago look weirdly different from modern cells, and evidence now suggests they are of a life form that couldn't control its structure, reports **Michael Le Page**

THE oldest rocks on Earth contain mysterious fossils of cells that appear unlike anything alive today, leaving biologists puzzled as to how they evolved. Now, experiments have shown that the fossils could be of primitive cells that lacked the ability to fully control their shape, making them a precursor to the modern cells we see today.

Sedimentary rocks that formed up to 3.8 billion years ago – not long after Earth itself – appear to contain fossilised cells that could be traces of very early life. These microfossils, first unearthed in 1987, have been found in multiple locations around the world, but aren't what biologists expected.

The first living cells are assumed to have been even simpler than the simple cells alive today, such as bacteria. Modern bacteria are tiny – just 1 or 2 micrometres wide – with no internal structures. But the fossilised cells found in ancient rocks are larger, at about 60 to 70 micrometres across, and seem to have internal structures, says Dheeraj Kanaparthi at the Max Planck Institute of Biochemistry in Germany. "These fossils look too complex. They're also too large," he says. "What we find is always baffling."

As a result, there is intense debate about what created these fossils and whether they really are the remains of living cells. Now, Kanaparthi has stumbled across a possible answer while studying bacteria growing around freshwater springs at the bottom of the very salty Dead Sea. Some of these bacteria had bizarre shapes, and he eventually realised that they were a type of cell without a cell wall, named L-forms after the Lister Institute in London where they were discovered in the 1930s.

Normally, the rigid cell wall of bacteria determines their shape, like putting a water balloon in a box, but stressful conditions can strip this wall away. In most situations, such "naked" bacteria swell and burst due to osmosis, as they absorb too much water. But in salty conditions, these L-forms can survive and sometimes even grow and replicate.

Kanaparthi and his colleagues have now shown that when L-forms are put in high salinities like those that might have existed in the coastal regions where the ancient fossils formed, they acquire structures that closely resemble some of the enigmatic microfossils.

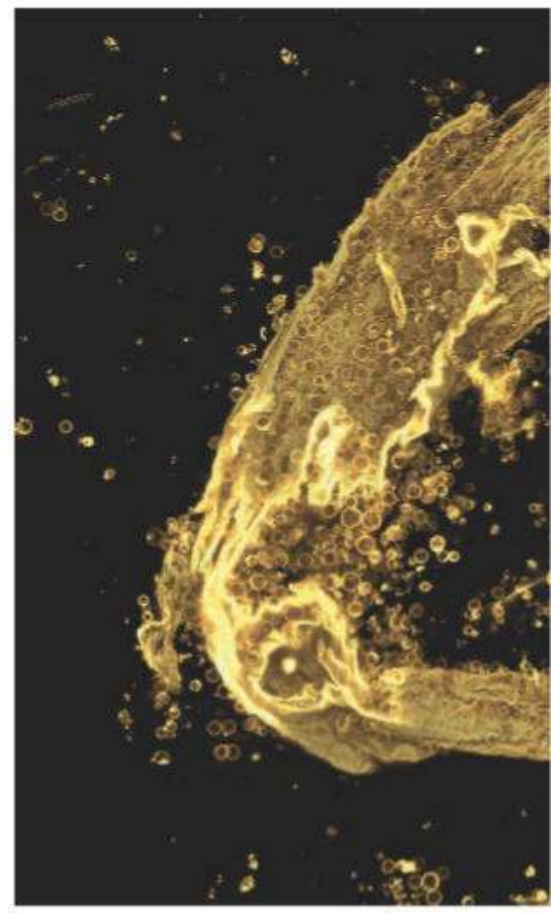
Depending on which salts are present in what levels, the cells grow very large and lots of new cells form within them, creating the illusion of internal structures like those in complex cells. The new cells are released when the parent cell bursts apart. These L-forms resemble microfossils found in the 3.4-billion-year-old rocks of the Strelley Pool formation in Western Australia.

In other conditions, the L-forms grow into long strings that split into separate cells, resembling microfossils found in the 3-billion-year-old Cleaverville formation, also in Australia.

"We thought these cells would just grow into large bubbles and then split apart into 1000 pieces," says Kanaparthi. "But actually, they reproduce in a very defined manner."

In the absence of a cell wall, the shape of these bacteria and how they reproduce are determined by the conditions to which the L-forms are exposed rather than their genes, the team found. "They're at the mercy of the environment," says Kanaparthi.

Their reproduction is also rather inefficient, as lots of the content of the parent cell tends to leak out during the process. However, this leakiness could



Bacteria without cell walls can create structures (main image) like those in ancient rocks from South Africa (inset)

Mars rock shows hints of ancient life

Signs of ancient life in rocks aren't just limited to Earth, as a discovery on Mars by NASA's Perseverance rover shows. The rock it has found, nicknamed Cheyava Falls, hints that the planet supported living microbes billions of years ago – but for now, there is no way to be sure if life really existed there.

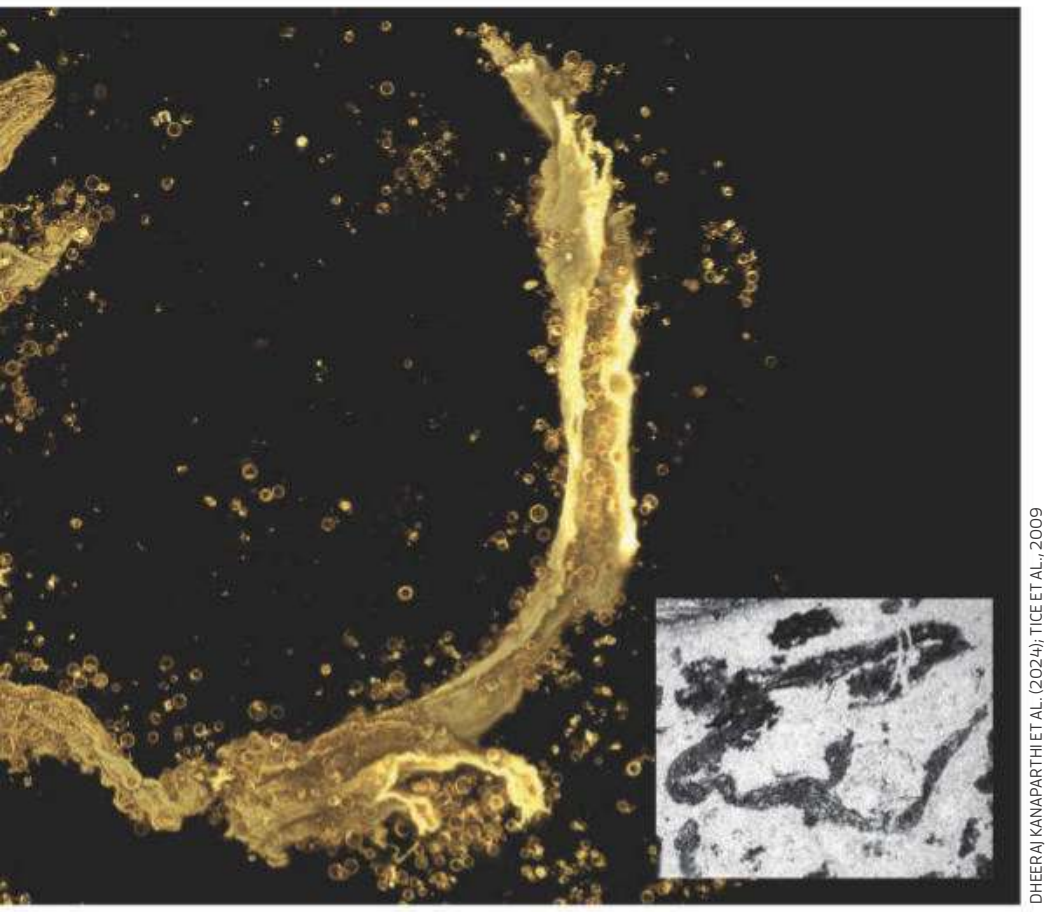
The rock measures about 1 metre by 0.6 metres and is mostly reddish, with thin veins of white calcium sulphate that probably formed when water flowed through fissures, depositing minerals in the cracks. Water is one of the ingredients necessary for life as we know it.

Between the streaks of white are strange, light-coloured "leopard spot" splotches (see image, right), each just millimetres across and ringed with dark material containing iron and phosphate. "These spots are a big surprise," said David Flannery at the Queensland University of Technology in Australia in a NASA press release. "On Earth, these types of features in rocks are often associated with the fossilized record of microbes living in the subsurface." That is because the type of chemical reaction that creates such spots on Earth rocks can also provide useful energy for microbes.

In the area near the rock, Perseverance also detected other organic compounds often considered building blocks of life. These signatures can be created without the involvement of any living organisms, though.

The rover has added a sample of Cheyava Falls to its stash, which is intended to be brought back to Earth by a future mission for further analysis. Leah Crane

NASA/JPL-CALTECH/MSSS



DHEERAJ KANAPARTHI ET AL. (2024); TICE ET AL., 2009

explain mysterious carbon deposits found outside some microfossils, says Kanaparthi. "We were able to reproduce not just the morphologies of the cells, but also all the associated organic carbon structures."

The researchers also looked at how L-forms might be preserved and fossilised. They showed, for instance, that the remnants of L-forms can generate microscopic structures that resemble those

"These cells could represent how early life forms proliferated and explain the early microfossils"

found in the 3.4-billion-year-old Buck Reef rocks in South Africa (see images, above).

Based on these findings, the team proposes that primitive cells also lacked a cell wall and weren't in full control of their shape and reproduction. They may only have gained this ability when cell walls evolved around 2.5 billion years ago (bioRxiv, doi.org/gsx4cf).

The resemblance between the L-forms and the proposed microfossils is striking, says Jeffery Errington at the University of Sydney, Australia, who, in 2013, first suggested that L-forms might reflect what primitive cells were like. "Most scientists would be cautious because [it] is a very long time for a fossil to be preserved," he says. "Nevertheless, the results certainly provide support for the idea that primitive L-form-like cells inhabited the planet soon after the Earth cooled sufficiently to support carbon-based chemistry."

"It is challenging to determine if the conditions used truly reflect those of early Earth," says Dennis Claessen at Leiden University in the Netherlands. "Nonetheless, I agree that these cells could represent how early life forms proliferated and explain the early microfossils discovered." ▮

Technology

AI grabs silver medal at human maths competition

Alex Wilkins

AN ARTIFICIAL intelligence from Google DeepMind has achieved a silver medal score at this year's International Mathematical Olympiad (IMO), the first time an AI has made it to the podium.

The IMO is considered the world's most prestigious competition for young mathematicians. Correctly answering its test questions requires mathematical ability that AI systems typically lack.

In January, Google DeepMind demonstrated AlphaGeometry, an AI system that could answer some IMO geometry questions as well as humans. However, it couldn't answer questions from other mathematical disciplines, such as number theory, algebra and combinatorics, which is necessary to win an IMO medal.

Google DeepMind has now released a new AI, called AlphaProof, which can solve a wider range of problems, and a new version of AlphaGeometry.

When the team tested the systems together on this year's IMO questions, they answered four out of six questions correctly, giving them a score of 28 out of a possible 42 points. This was enough to win a silver medal and just one point under this year's gold medal threshold.

At the contest in Bath, UK, at the end of July, 58 entrants won a gold medal and 123 got silver.

"The rate at which AI is improving is breathtaking," says Gregor Dolinar, the IMO president. "Missing the gold medal at IMO 2024 by just one point… is truly impressive."

At a press conference, Timothy Gowers at the University of Cambridge, who helped mark AlphaProof's answers, said the AI's performance was surprising and it appeared to find "magic keys" to answer problems in a similar way to humans. "I thought that these magic keys would probably be a little bit beyond what it could do," said Gowers.

AlphaProof works similarly to Google DeepMind's previous AIs that can beat the best humans at chess and Go. All of these AIs rely on a trial-and-error approach called reinforcement

3 days
were needed for the AI to find solutions that take humans hours

learning, where the system finds its own way to solve a problem over many attempts. However, this method requires a large set of problems written in language that the AI can understand and verify, whereas most IMO-like problems are written in English.

To get around this, Thomas Hubert at DeepMind and his colleagues used Google's Gemini AI, a language model like the one that powers ChatGPT, to translate these problems into a programming language called Lean so the AI could learn how to solve them. It also produces its answers in Lean, so they can be easily checked.

However, it took AlphaProof up to three days to find some solutions instead of the 4.5 hours per three questions that competitors are allowed.

Hubert says he hopes AlphaProof will help improve the accuracy of Google's large language models, like Gemini.

Trading firm XTX Markets has offered a $5 million prize – called the AI Mathematical Olympiad – for an AI capable of achieving a gold medal at the IMO, but AlphaProof isn't eligible because it isn't publicly available. ▮

Briefing

Is Olympic drug testing good enough?

Measures are in place to catch athletes at the games who use performance-enhancing drugs. **Christa Lesté-Lasserre** examines whether they are up to the job

WITH the 2024 Paris Olympics well under way, the International Olympic Committee is aiming to ensure the games are "clean" by rooting out athletes who use performance-enhancing drugs.

To do this, it relies on the World Anti-Doping Agency (WADA), which develops and coordinates anti-doping rules and policies across all sports and countries. Here's how the agency is attempting to catch cheats.

What doping agents are authorities looking for?

Every year, WADA publishes updated lists of prohibited substances. The most commonly spotted ones are anabolic steroids, such as trenbolone and oxymetholone, both of which increase muscle mass and strength. These made up 42 per cent of positive results from competitive sporting events in 2022, according to a WADA report.

Diuretics made up 16 per cent of samples that failed doping tests. These increase urine output, leading to a lighter body weight, and can hasten the elimination of other doping agents.

Other substances found include stimulants, hormone and metabolic modulators, cannabinoids, peptide hormones, glucocorticoids, beta-2 antagonists, narcotics and beta blockers. Overall, fewer than 1 per cent of samples are positive, reports WADA.

Is there a lag between a new drug emerging and a way to test for it?

As doping agents are evolving, so is the art of detection, says a WADA spokesperson. "WADA's science and medicine department is tasked with staying at the forefront of new substances and methods," they say. The agency collaborates with the pharmaceutical industry to stay on top of the latest trends. "Innovative research leads to the identification of new doping trends, new substances, new doping methods and new detection approaches," says the spokesperson.

Furthermore, specialised facilities store all samples for 10 years, opening the door to further analyses when testing technology has advanced.

The athlete biological passport, an ongoing electronic record for each competitor, can also flag doping indirectly, by picking up changes in samples over time. This contains biological markers for each athlete throughout their sporting career. Regular blood and urine tests provide measures of naturally occurring steroids, growth hormones, haemoglobin and red blood cells, for example.

Software analyses of each new sample determine if such measures fall out of the athlete's normal range. If they do, scientific experts investigate to distinguish between potential illness, doping or an inconsequential fluke.

The passport has been useful in detecting "blood doping", in which athletes inject themselves with additional red blood cells or drugs to enhance red blood cells to carry more oxygen to the muscles.

"Hair samples aren't used, but they could distinguish between real doping and contamination via kissing"

What about gene doping?

CRISPR-edited genes could be injected to modify gene activity in a performance-enhancing way. To combat this, WADA has created the Gene and Cell Doping Expert Advisory Group to work with researchers to develop detection methods for gene manipulation, it says.

Is there a concern athletes will use carbon monoxide inhalation, as seen in the Tour de France?

Recent research suggests that regularly inhaling low doses of carbon monoxide, which isn't banned in sport, can increase the amount of oxygen an athlete's body can absorb and use during exercise, known as the VO_2 max.

WADA's Prohibited List Expert Advisory Group has discussed this issue, but hasn't reached a consensus about whether the toxic gas has a performance-enhancing effect, says the agency's spokesperson. "No sufficiently robust data currently supports that proposition. It is, however, generally acknowledged that it can be dangerous to use, so it would not be recommended."

What samples are used in testing?

WADA mainly requires urine samples, although blood samples can be provided in certain cases.

Pascal Kintz at the Institute of Legal Medicine in Strasbourg, France, thinks hair and nails should also be part of official anti-doping programmes, because they can provide a longer-term picture.

Hair, for example, grows at about 1 centimetre per month. Tests can therefore detect substances in each centimetre of a strand to determine roughly when, and how often, a doping agent was consumed.

For example, eating beef contaminated with growth hormones can sometimes trigger a positive urine test, says Kintz, but a hair analysis could tell whether or not it was true doping. Hair samples could also distinguish between doping and accidental contamination from kissing and other intimate contact with partners who use such substances.

At this time, WADA hasn't included hair or nail analyses in its policy and won't accept them to overturn a positive urine or blood result from the games, says the agency's spokesperson. ▮

AYTAC UNAL/ANADOLU VIA GETTY IMAGES

The 2024 Olympic Games are being held in Paris, France

Astrophysics

We may finally know what caused the biggest cosmic explosion ever seen

Alex Wilkins

THE most powerful explosion ever glimpsed contains a mysterious signal thought impossible to exist. That signal gives us our first detailed look inside a gamma ray burst and suggests they involve matter and antimatter annihilating.

Gamma ray bursts (GRBs) are the most powerful blasts of radiation in the universe and are generated in cosmic explosions and collisions. But exactly how the radiation is produced, and what the jets of energy contain, has been hard to pin down.

Much of this mystery comes from the spectrum of the light we see. Unlike the light that we observe from other objects in the universe, which contains distinctive spikes that can tell us about the matter that produced this burst of energy, the spectrum of light from gamma ray bursts seems smooth and featureless.

In the 1990s, researchers became excited at the prospect that some GRBs appeared to show distinct lines. But after careful analyses, they found these were statistical errors and concluded that GRB spectra couldn't be spiky.

Now, Maria Ravasio at Radboud University in the Netherlands and her colleagues have discovered that GRB221009A, discovered in 2022 and dubbed the brightest explosion since the big bang, in fact contains an energetic peak at about 10 megaelectronvolts.

"The first time I saw the line, I thought I did something wrong," says Ravasio. But after detailed statistical analysis and ruling out problems with the observation instrument, she and her colleagues concluded that the spectral spike was genuine. "When I realised it wasn't an error, I got goosebumps," says Ravasio.

Because almost all GRBs show a similar distribution of energies, astronomers analyse new GRB detections using data analysis methods that work best with this pattern. But Ravasio and her team instead used a method that allows for peaks, and they found that this fit the data better. "That part of the GRB spectrum has been the same for years, and nobody was looking into it," says Ravasio.

The peak they saw points to a specific physical process behind GRBs that is missing from our best models of them. To focus on what this might be, the researchers worked under the assumption that there were no complete atoms in the jet, due to how energetic it must have been. This left one plausible explanation: the annihilation of electrons with their antimatter counterparts, positrons. Such annihilation would produce gamma rays at a peak of 511 kiloelectronvolts (*Science*, doi.org/m9zg). "This is already telling you the composition of the jet," says Ravasio.

Huge stars collapsing or colliding can launch out bursts of gamma rays

NASA'S GODDARD SPACE FLIGHT CENTER/A. SIMONNET, SSU

The higher 10 MeV peak that the researchers observed was because the energy spectrum was shifted by the fast-moving jet that produced the radiation, similar to how the siren of an ambulance moving towards you sounds higher pitched.

Finding a GRB with a distinctive line is "one of the biggest surprises in our field in more than a decade", says Eric Burns at Louisiana State University. "It's rather astounding. We totally missed this because we didn't even look for it." ▮

Environment

Biodegradable plastic may actually be worse for plants

PLASTICS that biodegrade into microplastics seem to reduce soil quality and affect plant growth more than conventional ones, at least in the short term.

Global plastic production reached 400 million tonnes in 2022, most of which isn't recyclable. Large pieces of plastic that end up in the environment can be weathered into smaller and smaller pieces, until these are sometimes no longer visible.

To reduce pollution by these microplastics, some industries have turned to biodegradable plastics, known as bioplastics.

Now, Jie Wang at Jiangnan University in China and her colleagues have collected samples of soil containing no visible plastic from a forested area around the university. After removing any debris, stones and vegetation, the researchers dried the soil and measured its pH, organic matter and nutrient levels.

They added conventional microplastics, made from the common plastic polyethylene, to some of the samples and bio-microplastics to others, then attempted to grow wheatgrass. The plant was also grown in unaltered soil to provide a comparison.

10 days
in soil polluted by bio-microplastics stunted plant growth

Just 10 days later, the bio-microplastics had significantly reduced key minerals such as nitrogen in the soil, lowered its microbial diversity and stunted plant growth. The polyethylene microplastics had much less of an effect (*Science of The Total Environment*, doi.org/gtt6g6).

It is unclear why bio-microplastics caused this outcome. However, nitrogen is essential for producing chlorophyll, the green pigment that allows plants to absorb energy from the sun. Reduced nitrogen levels in the soil may therefore affect plant growth.

The team also added extra water to some samples to simulate a flood. Bioplastics had an even greater negative effect in these samples than in the other ones, possibly because the excess water encouraged pathogenic bacteria in the soil that affect plant growth.

"This study represents an important step in understanding the impacts of biodegradable plastics," says Samuel Cusworth at ETH Zürich in Switzerland. "Biodegradable plastics are not necessarily a safe and sustainable alternative and their use must be carefully considered." ▮

Bárbara Pinho

Health

The truth about Alzheimer's drugs

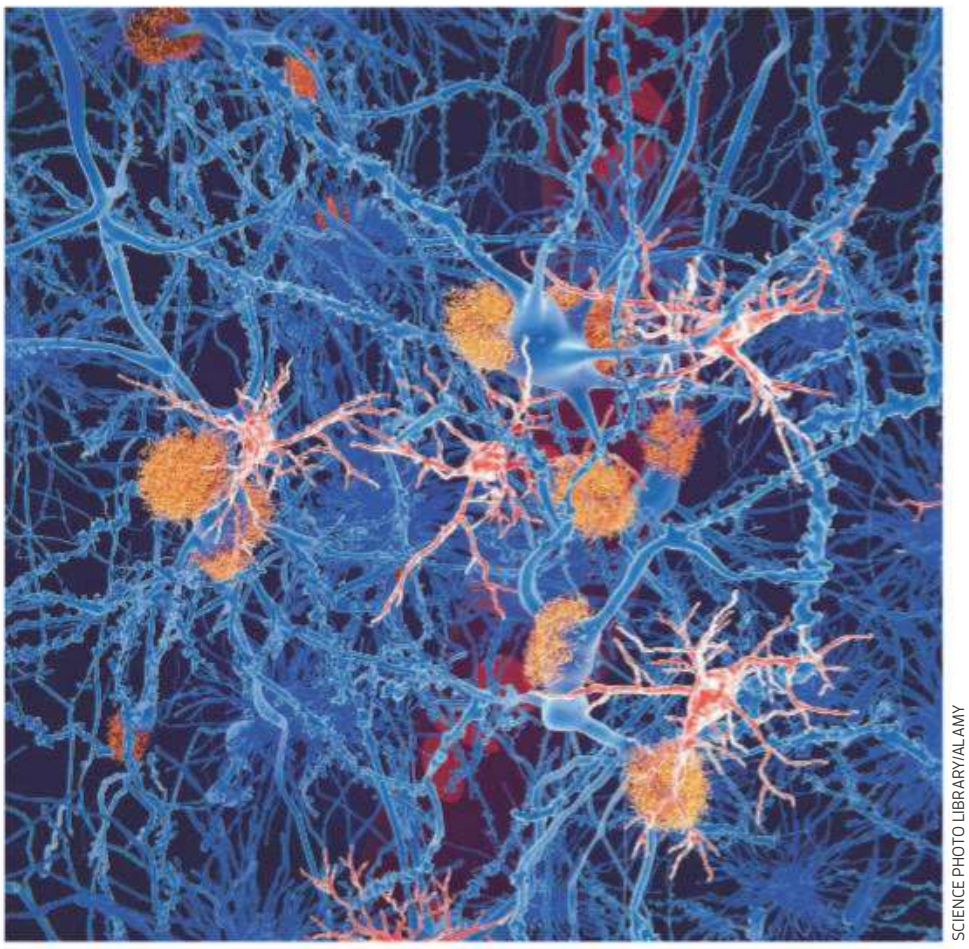
A new class of drugs has been hailed as a breakthrough, but are the treatments the game changers they are being billed as, asks **Grace Wade**

IN EARLY July, the US Food and Drug Administration (FDA) approved a treatment called donanemab for people with early-stage Alzheimer's disease. It is the second drug shown to slow the condition's progression, and the third FDA-authorised medication that clears the amyloid proteins that accumulate in the brains of people with Alzheimer's.

The FDA's approval of three new drugs – donanemab, lecanemab and aducanumab – in just over three years has led some to declare a leap forward in Alzheimer's disease treatment. Japan, South Korea, China, Hong Kong and Israel have also approved lecanemab, while the United Arab Emirates has approved aducanumab.

Donanemab and lecanemab are the first drugs to curb the disease's advancement: previous therapies only tried to counteract symptoms, such as memory loss. But the new treatments have been controversial and concerns linger about their safety. On 26 July, an advisory body to the European Union recommended against approving lecanemab, citing its side effects.

All of these drugs use antibodies engineered to target and remove amyloid proteins from the brain. The plaques these proteins form are believed to be critical in driving the progression of Alzheimer's, an idea known as the amyloid hypothesis. However, this hasn't been confirmed as the cause of the condition, which has raised concerns that we are moving ahead with drugs that target amyloids before we know for sure they are the culprit behind the disease.



SCIENCE PHOTO LIBRARY/ALAMY

Illustration of amyloid plaques (orange) among brain cells

Drug trial difficulties

The race to develop amyloid-clearing drugs began when a landmark study in 1999 showed that removing amyloid plaques reversed cognitive deficits in rodents. Two decades on, however, all the drug candidates had failed in phase III clinical trials (see "Clinical trial phases", right). This raised serious doubts about them as Alzheimer's treatments and, consequently, about the amyloid hypothesis.

One of those drugs was aducanumab, made by US firm Biogen. In 2015, the company launched two phase III clinical trials with almost 3300 people who had early-stage Alzheimer's disease and amyloid plaques in their brains. Early results suggested the drug had little to no effect: although one trial showed that cognition declines at a roughly 20 per cent slower rate in those on a high dose of the drug than in those given a placebo, the second trial found no difference.

Biogen halted trials in 2019, but seven months later, it changed course. The company said a new analysis of longer-term outcomes from the second trial indicated that aducanumab did, in fact, slow cognitive decline. In 2020, Biogen submitted the drug for approval.

But many experts were concerned, especially given the drug's risks. About 40 per cent of participants taking aducanumab experienced serious side effects, known as amyloid-related imaging abnormalities (ARIA), in which fluid leaks from blood vessels in the brain. Most cases of ARIA are asymptomatic and resolve on their own, but some can lead to headache, seizures or even death. Four deaths have been reported related to aducanumab, but Biogen said in a statement that none of the 11 deaths during phase III trials was attributable to the drug. Biogen didn't respond to a request for comment on aducanumab's side effects.

In 2020, an advisory panel to the FDA recommended against the drug's approval. Yet in 2021, the FDA granted this, pointing to its ability to significantly clear amyloid plaques. In a statement, the FDA said the drug "is reasonably likely to predict a clinical benefit to patients", but trials showed mixed results. The controversial decision prompted a government investigation and sowed further doubts about the amyloid hypothesis and the drugs resting on it. Biogen announced earlier this year it would discontinue aducanumab.

A new hope

"It was very messy in the end and, unfortunately, it left a lot of uncertainty and lack of enthusiasm [for developing and prescribing aducanumab]," says James Noble at Columbia University, New York.

Two other amyloid-clearing drugs have since alleviated some

30%
Approximate reduction in rate of cognitive decline with donanemab

$32,000
Cost of one year of infusions of donanemab

2
Number of treatments shown to slow progression of Alzheimer's

of the doubts left in aducanumab's wake. The first, lecanemab, is made by Japanese pharmaceutical company Eisai. In a 2022 clinical trial of nearly 1800 people with early-stage Alzheimer's disease and amyloid plaques, those given lecanemab had a 27 per cent slower rate of cognitive decline

"These medications provide the best chance of slowing down something we don't have good treatments for"

after 18 months compared with those given a placebo. This translates to a roughly 0.5-point difference on an 18-point cognitive scale.

While that may seem small, surveys show it has meaningful effects. A 2023 study found that declines in quality of life slowed by about 50 per cent in people taking lecanemab compared with those given a placebo. This was the first time a drug had been shown to slow the progression of Alzheimer's.

The only other drug with similar effects is donanemab from US pharmaceutical company Lilly. In a 2023 study of more than 1700 people with early-stage Alzheimer's disease, donanemab slowed cognitive decline by almost 30 per cent. Combined, these results have provided the strongest evidence yet for the amyloid hypothesis. But they also make clear there are other processes driving the condition.

"The promise that we've been trying to deliver on as a field finally came to be," says Noble. "These medications provide the best chance of slowing down something that we don't otherwise have good treatments for."

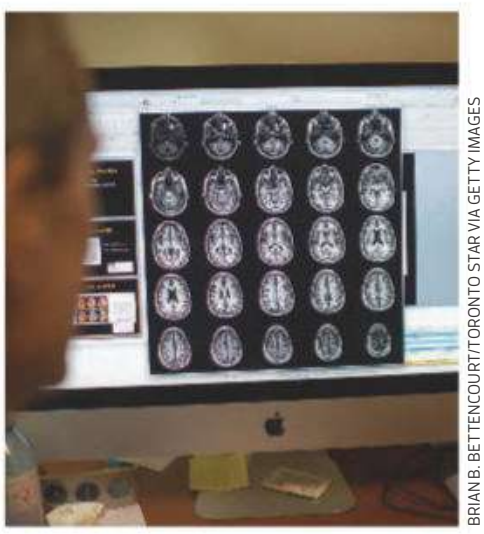
No trial has compared donanemab and lecanemab head-to-head, so it is impossible to say if one is more effective than the other. However, Noble says donanemab may be slightly more potent based on clinical trial results. Yet this could be due to differences in the trials, not the drugs, says Steven Hersch at Eisai.

For instance, a larger proportion of participants in the donanemab trial were at a later stage of the disease than those in the lecanemab trial. This means they probably experienced a more rapid rate of decline, making donanemab's effects more pronounced, says Hersch.

There may also be differences in side effects between medications. In clinical trials, nearly 37 per cent of people taking donanemab developed ARIA compared with 15 per cent of those in the control group. In the lecanemab trial, the same was true for less than 22 per cent of participants taking the drug compared with almost 10 per cent of the control group.

Most instances of ARIA didn't cause serious complications. But about 6 per cent of those in the donanemab group had severe brain bleeds, which contributed to three participants' deaths,

Regular brain scans are required when taking Alzheimer's drugs



BRIAN B. BETTENCOURT/TORONTO STAR VIA GETTY IMAGES

according to a spokesperson for Lilly. Nearly 3 per cent of those given lecanemab developed severe brain bleeds. Three participants taking lecanemab also died during the trial, though Eisai says these can't be attributed to the drug. An Eisai spokesperson says that four deaths during an extended phase of the clinical trial were possibly related to the drug.

Risk vs reward

"Certainly, there are risks associated with these drugs," says Noble. Evidence suggests that people with a genetic variant known as *APOE4*, which is one of the strongest genetic risk factors for Alzheimer's, are at a higher risk of severe brain bleeds. Noble says clinicians may want to consider genetic testing before starting people on these medications.

Ultimately, both lecanemab and donanemab lead to only modest changes in cognition and share a similar risk-benefit profile. "Some people are uncomfortable with the risks considering the relatively modest benefit," says Noble. "Others are the first to line up and say, if it can do anything for me, I want to start it now." But accessing the drugs isn't simple or cheap. They require time-consuming infusions and regular brain scans, though Eisai has developed an injectable form of lecanemab.

The drugs differ a bit in how they work. Donanemab only clears plaques. Lecanemab does this too, but also targets amyloid proteins that haven't accumulated yet. So people can stop using donanemab once scans show they no longer have plaques, but those on lecanemab are recommended to continue using it. A year's supply of lecanemab costs $26,500 while donanemab costs $32,000.

Because it targets unbound amyloid proteins, lecanemab may be beneficial in treating people at an earlier stage of the disease, before plaques start forming. Studies looking into this are currently under way and should conclude in 2027, says Hersch.

"These aren't perfect drugs. They aren't a cure," says Noble. "But they are game changers in that they've given us hope in making an impact on the disease in ways that we'd never really had before." ▮

Clinical trial phases

Pharmaceutical companies must show that a drug is safe and effective in order to seek its authorisation. They do so by testing the drug in several phases of clinical trials.

Phase I trials involve between 20 and 100 people with the condition being treated. Their purpose is to test the safety of a medication and to identify the proper dose.

Phase II trials usually include several hundred people, making them large enough to begin assessing a drug's efficacy. They also provide additional data on any side effects.

Phase III trials are usually the final step before a drug is submitted for regulatory review. They can include several thousand people and they demonstrate whether a treatment works. Their size also makes it possible to identify rare side effects or long-term risks that may have gone undetected in smaller trials.

Archaeology

Bronze Age had a modern economy

An analysis of 20,000 metal objects from ancient Europe suggests human economic behaviour may not have changed much over the past 3500 years, reports **Becky Ferreira**

PEOPLE in Bronze Age Europe earned and spent money in much the same way as we do today, indicating that the origins of the "market economy" are far more ancient than expected.

That is the controversial conclusion of new research that challenges the view that elites were the dominant force in Bronze Age economies, and proposes that human economic behaviour may not have changed much over the past 3500 years – and perhaps even longer.

"We often tend to romanticise European prehistory, but the Bronze Age was not a fantasy realm where townsfolk and peasants were merely the background for some great lord providing for their needs," says Nicola Ialongo at Aarhus University in Denmark. "It was a very familiar world where people had families, friends, a social network, marketplaces and a job, and ultimately had to figure out how to make ends meet."

Europeans of the Bronze Age, a period that spans 3300 to 800 BC, weren't meticulous bookkeepers like people of some other ancient societies, such as Mesopotamia. But Ialongo and Giancarlo Lago at the University of Bologna, Italy, say important revelations about their daily lives, and the roots of our own modern economic behaviour, can be found in the troves of metal fragments, known as hoards, that they left behind.

Lago and Ialongo have analysed more than 20,000 metal objects from hoards buried in Italy, Switzerland, Austria, Slovenia and Germany during the Bronze Age. The pieces appear in many forms, but around 1500 BC, they start to become standardised by weight, a shift that many historians believe distinguishes them as a form of pre-coinage money.

J. LIPTÁK/LANDESAMT FÜR ARCHÄOLOGIE SACHSEN

Above: A hoard of Bronze Age metal fragments from Weissig, Germany. Below: Copper and tin were smelted to make bronze

"It was a very familiar world where people had families, friends, a social network, marketplaces and a job"

SCIENCE HISTORY IMAGES/ALAMY

"The discovery of a widespread measurement and weight system makes it possible to model things that have been known about for centuries in a way that they have never been modelled before," says Ialongo.

To that end, the team found that the weight values of the huge sample follow the same statistical distribution as the daily expenses of a modern Western household: small everyday expenses, represented by lighter fragments, made up the vast majority of consumption patterns, while larger expenses, represented by heavier fragments, were comparatively rare (*Nature Human Behaviour*, DOI: 10.1038/s41562-024-01926-4). This pattern is analogous to what you might find in a modern wallet, with lots of smaller banknotes and very few high-value ones.

Lago and Ialongo interpret the findings as evidence that Bronze Age economic systems were regulated by supply and demand market forces, in which everyone participates proportionally to how much they earn. This hypothesis stands in contrast to an influential view put forth in the 1940s by the anthropologist Karl Polanyi, who cast modern economies based on monetary profit as a new and distinct phenomenon from ancient economies centred around barter, gift exchange and social standing.

Hard currency

"The argument, I think, will prompt discussion among archaeologists and economic anthropologists, who have been labouring under false assumptions about the antiquity of market economies for decades," says Richard Blanton at Purdue University in Indiana. "For me, the paper throws a whole new light on the function of the bronze hoards and their potential for the use of bronze pieces as units of exchange."

However, Erica Schoenberger at Johns Hopkins University in Maryland is sceptical of the team's conclusions. "It's risky to assume that ordinary people in pre-modern times used money in ordinary economic ways," says Schoenberger. "Medieval English peasants, for example, only began selling their produce for money when their lords began demanding money in place of in-kind rents and taxes. The peasants handed most – if not all – of that money directly to the lord. They sold in order to get money, but they did not use it to buy things they needed. We're still a long way from modern economic behaviour [in the Middle Ages]."

Lago and Ialongo hope their research will inspire similar work on artefacts from different regions and cultures. They suggest that market economies naturally arose across cultures, and aren't modern or special inventions of Western societies. ▮

Chemistry

We may soon be able to make the heaviest element

Karmela Padavic-Callaghan

THE third-heaviest element in the universe has been made in a way that offers a route to synthesising the elusive element 120, which would be the heaviest element in the periodic table.

To create livermorium, or element 116, Jacklyn Gates at Lawrence Berkeley National Laboratory in California and her colleagues smashed a beam of charged titanium atoms into a piece of plutonium. It is the first time titanium has been used like this and physicists think a titanium beam will be crucial for creating the hypothetical element 120, also known as unbinilium, which would have 120 protons in its nucleus.

The researchers started with rare isotopes of titanium, which they vaporised at 1650°C (around 3000°F). They used microwaves to turn the vapour into a charged beam, which they fed into a particle accelerator. When the beam reached roughly 10 per cent of the speed of light and struck the plutonium target, the resulting debris hit a detector that revealed signatures of two atoms of livermorium.

Each atom rapidly decayed into other elements, because the stability of atomic nuclei decreases as the mass of an atom increases. Yet the measurement was so precise that there is only about a one in a trillion chance the finding was a statistical fluke, says Gates. She presented the findings on 23 July at the Nuclear Structure 2024 conference at Argonne National Laboratory in Illinois.

The heaviest human-made element so far – element 118, also known as oganesson – has two more protons than livermorium and was first synthesised in 2002. Gates and her colleagues plan to try creating element 120 in 2025, once they have replaced the plutonium target with the heavier element californium. ▮

Technology

Social media firms change their policies after bad press

Chris Stokel-Walker

NEGATIVE news stories about social media platforms appear to be highly effective at pressuring companies into changing their policies.

Christian Katzenbach at the University of Bremen, Germany, and his colleagues analysed policy changes across Facebook, Twitter (now X) and YouTube between 2005 and 2021, as well as how media coverage from 26 major English-language publications affected their policies. (*New Scientist* wasn't among the publications picked by the researchers.)

"There are really significantly more changes in the policies by the platforms in the weeks and months after an increase of negative reporting," says Katzenbach. For every negative story about a platform, the likelihood of that platform changing its user policies increased by 6 per cent.

To measure negative reporting, the researchers looked at the content of news stories using an AI model that classifies sentiment. The AI had been trained on a dataset of 11,000 news stories about US politics that were annotated by humans.

Facebook was the subject of the most negative reporting, with around 37 per cent of news stories from the 26 major publications being seen as negative. Around 26 per cent of coverage about YouTube and Twitter was deemed negative.

37%

of news stories about Facebook were negative (2005-21)

The proportion of negative coverage about all platforms significantly increased after 2018, when allegations of the misuse of Facebook user data by the consulting firm Cambridge Analytica came to light (*Political Communication*, doi.org/m9p8).

"We've seen that platforms do respond to public criticism," says Katzenbach. For example, in 2014, a campaign dubbed #FreetheNipple pressured Facebook into allowing users to post photos of breastfeeding. However, those rules, and how they are enforced, remain a topic of debate: Meta's oversight board told the platform to clarify its policies in January 2023 following confusion over what did and didn't breach policy.

Another example the researchers highlight came during the 2020 US presidential election campaign, when Twitter announced it would ban political advertisements from the platform. Facebook was then criticised in the media for not fact-checking or banning political ads itself, and near the end of the year it too started to do this.

"I think it's very much true that negative media coverage affects the way platforms govern and behave," says Carolina Are at Northumbria University, UK. Are believes that deciding policies through media coverage alone isn't enough to protect users. "A strategy that relies on PR is just a Band-Aid approach for the issues that we're facing right now," she says.

Are says a more proactive approach is needed to regulate social media platforms, including legislation that checks how policies affect users: "If all we get to do through the use of PR is to change policies, then we're taking for granted that platforms are always going to run the system as they are – while we need to hold them far more accountable than that."

Katzenbach echoes this view. "Definitely you need regulation, and strong regulation," he says. "Media coverage cannot substitute that." ▮

Facebook's Mark Zuckerberg facing a hearing about Cambridge Analytica in 2018

ERIN SCOTT/ZUMA WIRE/ALAMY LIVE NEWS

Technology

AI can predict when dangerous tipping points will occur

Karmela Padavic-Callaghan

KAZUHIRO NOGI/AFP VIA GETTY IMAGES

COMPLEX systems like forest ecosystems, stock markets or the power grid can suddenly start behaving very differently, and artificial intelligence can now predict when this will happen. Identifying such tipping points may help avert disastrous collapses in biology or human infrastructure.

"History is full of harmful critical transitions, such as financial market crashes, disease outbreaks and blackouts," says Gang Yan at Tongji University in China.

To make predicting such transitions more precise, he and his colleagues combined two different types of artificial intelligence called neural networks. They optimised the first one to understand the functioning of and connections across systems structured like large networks with many nodes. For example, in an ecosystem, each node would be a geographical location where researchers would collect data about how many animals or trees live there. Nodes could also be different parts of the power grid or areas where disease outbreaks are occurring.

The team designed the second neural network to analyse how systems change over time. So the first network processed data about the nodes and the interactions between them, then fed this into the second network, which detected recurring patterns in the data and predicted future tipping points.

Yan says past studies focused on identifying particular features of data that increased or decreased as a tipping point approached, but his team's AI goes further. "It aims to pinpoint the precise conditions that lead to system collapse, asserting: 'Watch out, if the system reaches this [specific] condition, it will collapse immediately'," he says.

He and his colleagues tested the AI on a range of mathematical models and simulated data used to represent power grids, crop harvests and animal populations. In one test, they used real-world data on vegetation and rainfall in a forest ecosystem in Central Africa that suddenly became a savannah. The researchers trained the AI on simulations and the scarce data available for one part of the region, and then had it predict the value for annual precipitation at the tipping point for another. The AI correctly predicted what had actually happened to the ecosystem, even when it was only given data for about 10 per cent of the nodes to learn from (*Physical Review X*, doi.org/m9mk).

10%

of the data was enough for the AI to predict ecosystem change

Karen Abbott at Case Western Reserve University in Ohio says the new approach is "powerful", even though machine learning doesn't offer the same insight into why a tipping point occurs as a full-fledged mathematical model might. But the advantage of AI methods is that they can be applied to many systems instead of having to be formulated for a specific one each time, and they can be optimised to deal with sparse datasets, she says. "We really, really need both. Machine learning is telling us how to get more clues out of data, and theory is telling us what to do with those clues," says Abbott.

Now, Yan and his colleagues want to apply their method to more systems and work out why tipping points happen. "We aim to delve deeper into the algorithm's black-box nature to explicitly uncover the specific features used for predictions," he says. ▮

Financial markets can crash once they pass a tipping point

Infectious disease

How diseases like smallpox survived long ocean voyages

Rachel Nuwer

THE risk of pathogens lingering on a historical ship long enough to disembark with passengers has now been calculated.

Dangerous microbes hitched rides on lengthy sea voyages like that of Christopher Columbus, but it wasn't known how long they would survive these early ocean crossings, which took a month or more. "These ships aren't just carrying a pathogen like it's an extra piece of cargo – it needs to be spreading through the population," says Elizabeth Blackmore at Yale University.

Blackmore and James Lloyd-Smith at the University of California, Los Angeles, tailored a mathematical model of disease spread to ship environments. It incorporated factors like journey time, ship size, transmission intensity, susceptibility of those on board and the biology of the bug in question. They ran predictions for how long outbreaks of measles, influenza and smallpox would have been likely to last in various scenarios, and then compared their model's output with data about historically significant voyages between 1492 and 1918.

Their findings indicate that smallpox and measles could probably have persisted on certain early voyages, which lasted an average of five to 10 weeks. The risk of one of these diseases maintaining itself on board depended on how many infected individuals came aboard, how many people were present and how densely packed passengers were.

Unlike smallpox and measles, influenza is a fast-burning bug, and was unlikely to make a full oceanic crossing – at least early on. When steam travel was introduced in the 19th century, however, it sped up journeys and probably accelerated transmission of all three pathogens to the places where these ships docked (*PNAS*, doi.org/m9mm). ▮

Health

No amount of alcohol is good for you

Claims that moderate drinking could help people live longer are often based on flawed science

Michael Le Page

DRINKING even small amounts of alcohol reduces your life expectancy, rigorous research shows. A review of 107 studies concludes that only those with serious flaws suggest that moderate drinking is beneficial.

"People need to be sceptical of the claims that the industry has fuelled over the years," says Tim Stockwell at the University of Victoria in Canada.

While the risks of moderate drinking are small, people should be told that it isn't beneficial, says Stockwell. "It's maybe not as risky as lots of other things you do, but it's important that consumers are aware," he says. "I think it's also important that the producers are made to inform consumers of the risks through warning labels."

The best way to assess the effects of alcohol would be to randomly assign people to drink it or not in childhood and then monitor their health and drinking for the rest of their lives. Such studies can't be done, so researchers instead have to ask people about drinking habits and follow them over much shorter periods of time.

By the 2000s, numerous studies of this kind had suggested that the relationship between drinking and the risk of dying at a particular age made a J-shaped curve. That is, if people drank a little then their risk of dying of any cause went down a bit compared with non-drinkers, but drinking more led to a sharp increase in the risk.

Stockwell says he was convinced the science was settled at the time. But since then, he and others have shown that there are flaws in such studies.

The main problem is that they often don't compare people who have never drunk alcohol with those who have. Many studies instead compare people who no longer drink with those that still do. People who give up drinking, especially later in life, often do so because they have health problems, says Stockwell, so moderate drinkers appear healthier in comparison.

"The more you drink, the higher your risk of heart disease, which is obviously the main issue"

While some studies claim to compare current drinkers with "never drinkers", their definitions of the latter group often actually include occasional drinkers, says Stockwell (*Journal of Studies on Alcohol and Drugs*, doi.org/m9mp).

"The great majority of studies do not, in our opinion, deal with this potential source of bias," he says. "To be clear, people have attempted to deal with this. We don't think that they've dealt with it appropriately."

His team found that just six of the 107 studies adequately handled these sources of bias, and none of these found any reduction in risk with moderate drinking.

"The [high-quality] studies suggest a linear relationship," says Stockwell. "The more you drink, the higher your risk of heart disease, which is obviously the main issue even though our studies look at all-cause mortality."

The review shows clearly that poorer quality studies are more likely to suggest a beneficial effect, says Duane Mellor at the British Dietetic Association. But he says it doesn't consider the social aspects of moderate drinking. "It is healthier to socialise without the need for alcohol, but the benefits of spending time with others is still likely to be greater than the risk from the consumption of one to two units of alcohol," he says. ▮

Zoology

Komodo dragons have teeth capped with a layer of iron

ONE of the planet's fiercest reptiles, the Komodo dragon (*Varanus komodoensis*), reinforces its teeth with an iron cap.

These lizards are endemic to a number of Indonesian islands. Their prey include large animals like deer, pigs and water buffalo, and they can reach lengths of 3 metres and weights of 150 kilograms.

When he noticed orange serrations on the Komodos' teeth, Aaron LeBlanc at King's College London says he initially dismissed it as staining. "Only after visiting museum collections and looking at all of the teeth along the skulls of many Komodo dragon specimens was I convinced that I was looking at a novel adaptation," he says.

CHARLOTTE ELLIS/ZSL; DR AARON LEBLANC, KCL

Komodo dragons have an orange edge to their teeth (inset)

LeBlanc and his colleagues used high-powered X-rays at a synchrotron facility to probe the Komodos' tooth surfaces and determine the different elements that are found along the tooth.

"We quickly realised that iron was concentrated along the cutting edges and tooth tips, but not on other parts of the tooth," says LeBlanc. "This also precisely matches the orange staining we can see on the teeth under the microscope."

Compared with human teeth, Komodo dragon enamel is very thin, says LeBlanc. Along the serrations, the enamel is only 20 micrometres thick – the enamel in human teeth is about 100 times thicker.

The iron layer in Komodo dragon teeth is coated on top of this extremely thin layer of enamel. The team thinks it either gives the enamel extra strength or acts as a barrier against acidic digestive juices (*Nature Ecology & Evolution*, doi.org/m9mn).

Iron is readily available in the environment and the researchers think the cells that make the enamel switch behaviour for the final coat to produce this iron-rich finish. ▮

James Woodford

Archaeology

The great Neanderthal cook-off

Putting ancient human food-preparation techniques to the test reveals their culinary secrets

James Woodford

ARCHAEOLOGISTS have cooked and prepared five wild birds using only fire, their hands and stone tools to learn more about the culinary abilities of Neanderthals. The experiment shows it took considerable manual skill for our ancient relatives to butcher animals using flint blades without injuring themselves.

Neanderthals inhabited Europe and Asia until about 40,000 years ago. Hearths have been found at many Neanderthal sites, and we also have evidence they hunted large animals such as elephants and cave lions.

To gain insight into how these prehistoric humans lived, Mariana Nabais at the Catalan Institute of Human Paleoecology and Social Evolution in Tarragona, Spain, and her colleagues selected five birds that had died in a Portuguese wildlife rehabilitation centre. These were of a similar size and species to remains found at the Figuiera Brava and Oliveira archaeological sites in Portugal, which are associated with Neanderthals, dating to about 90,000 years ago.

"Raw birds processed with flakes show distinctive cut marks, especially around tendons and joints"

They were two carrion crows (*Corvus corone*), a common wood pigeon (*Columba palumbus*) and two Eurasian collared doves (*Streptopelia decaocto*).

The researchers plucked all five birds by hand. Next, they used flint flakes, which had been prepared to mimic Neanderthal tools, to butcher a crow and a dove. They baked the remaining birds on a bed of coals. The cooked birds could be easily pulled apart without stone tools, but the raw ones required a lot of effort using the flakes.

"Palaeolithic knives were indeed very sharp, requiring careful handling," says Nabais. "The precision and effort needed to use these tools without causing self-injury emphasised the practical challenges Neanderthals might have faced in their daily food-processing activities."

The researchers then analysed the bones for distinctive signs caused by the stone tools and the fire. They also identified wear marks on the flint tools (*Frontiers in Environmental Archaeology*, doi.org/m9mb).

Comparing the burn marks and tool scars on the bones with food remains from the Portuguese archaeological sites revealed that the marks aligned, says Nabais.

"Our experimental study demonstrated that raw birds processed with flakes show distinctive cut marks, especially around tendons and joints, while roasted birds show burn marks and increased fragility, leading to bone breakage," she says. "This study highlights the cognitive abilities of Neanderthals, demonstrating their capacity to catch and process small, fast-moving prey like birds."

Sam Lin at the University of Wollongong in Australia says the work demonstrates that Neanderthals wouldn't have needed tools to prepare cooked birds for eating, which could mean that some bones won't necessarily have tool scars. "They learned you can just rip a cooked wild bird apart the same way we eat a barbecue chicken," says Lin. ▮

Environment

Trees are even better for the climate than we thought

VINCENT GAUCI

Researchers measure gas exchange in Manu National Park in Peru

MICROBES living in the bark of trees are absorbing methane from the air, adding to the climate benefits that we knew trees give us.

Methane is a greenhouse gas that is responsible for about a quarter of human-caused global warming.

Some trees growing in water-logged soils can emit methane that was generated underground. But we also know that methane-eating microbes known as methanotrophs live on tree bark. Methanotrophs consume methane as their source of carbon and chemical energy, producing carbon dioxide and organic compounds.

To investigate this interplay, Vincent Gauci at the University of Birmingham, UK, and his colleagues took measurements from trees growing in well-drained soils around the world, determining the methane exchange between the atmosphere and the tree bark.

They found that, while most trees emit small amounts of methane at soil level, further up the trunk, the exchange flips and trees start absorbing atmospheric methane.

The CO_2 the methanotrophs produce is a much less potent greenhouse gas than methane, says Gauci. "There's tremendous benefit in that conversion to CO_2," he says.

The findings demonstrate that methanotrophs are removing methane from the atmosphere at a large scale, across temperate, boreal and tropical environments.

Trees growing in tropical locations are about 12 per cent better for the climate, once this methane-absorbing effect is factored in, while trees in temperate locations are about 7 per cent better. In total, trees could be absorbing between 24 million and 50 million tonnes of methane from the atmosphere each year, similar to the volume absorbed by the world's soils (*Nature*, doi.org/m9mc).

"Existing forests are that much more important than we thought, and we should preserve them," says Gauci. ▮

Madeleine Cuff

Space

Moon bases may need to be buried underground to avoid radiation

James Woodford

SHUTTERSTOCK/SHIVASHANKARA

The surface of the moon is inhospitable despite the great view

IF ASTRONAUTS on the moon are to avoid harmful radiation, long-term lunar bases may need to be shielded by 2 to 3 metres of regolith – the moon's surface layer of rock and dust.

Jingnan Guo and Mikhail Dobynde at the University of Science and Technology of China in Hefei have analysed how the thickness of a lunar base's shielding would affect radiation doses for people living on the moon. Their study includes using the lunar soil as protection as well as using additional artificial shielding.

There are two main kinds of radiation of concern: background levels of galactic cosmic rays, which pose a long-term cancer risk, and solar energetic particles (SEPs) associated with solar eruptions.

The SEPs can lead to acute symptoms of radiation exposure, such as skin injury and damage to areas involved in generating cells for the blood, which include bone marrow. In severe cases, exposure to SEPs can lead to death.

"For short stays on the moon without encountering intensive SEPs, the radiation effect should be small," says Guo. But if a solar eruption happens, the picture changes. At the end of the Apollo programme, for example, Apollo 16 landed astronauts on the moon for a few days in April 1972. This was followed by Apollo 17 in December that year. In between, there was a large radiation storm.

"There was such a big SEP event that happened in between… that it could have caused possible death to astronauts on the moon if they had been there unprotected," says Guo.

"A large radiation storm could have caused death to astronauts who were on the moon unprotected"

The study also found that too little regolith shielding can be worse than none, because lunar soils scatter radiation, generating secondary particles that can include neutrons. This secondary radiation peaks at depths of about half a metre but decreases rapidly lower beneath the surface.

"Neutrons have a large biological effect as they can efficiently interact with the human body to cause radiation effects in the internal organs," says Guo. "They can contribute more than 90 per cent of the total effective radiation when shielding is around 50 centimetres," says Guo.

The study found that bases at a depth of 3 metres would safely accommodate the same crew for more than 20 years without them exceeding lifetime and annual radiation limits set by space agencies (*Nature Astronomy*, doi.org/m9gb).

NASA and the Russian space agency impose different lifetime radiation dose limits – 600 millisieverts and 1000 mSv, respectively – on their astronauts. Both agencies also impose annual exposure limits. Natural background radiation exposure on Earth amounts to about 2.4 mSv a year.

If the lunar stay for a single crew is no more than a few months, 2 metres of total shielding should be enough, says Guo. Crew members could also be rotated back to Earth to avoid exceeding lifetime and annual radiation health limits, she says.

The most practical way to reduce radiation exposure would be to use natural shielding for bases by building them in existing caves or lava tubes or constructing habitats beneath the surface, says Guo.

Better predictions of solar storms will also be important, she says, to keep astronauts safe when they go outside the base for activities on the surface. ▮

Health

Spending time in space speeds up muscle ageing

Karmela Padavic-Callaghan

RADIATION isn't the only danger if you venture beyond Earth. A week in the microgravity of space ages muscle cells so much that their genetic activity looks similar to Earth-bound cells that have been ageing for years. This finding could explain why spending time in space impairs muscle function.

We know astronauts risk losing bone density and muscle mass due to low gravity in space. Now, Ngan Huang at Stanford University in California and her colleagues have analysed the effects of microgravity on muscle cell genetics.

The researchers grew human muscle cells in a scaffold of collagen fibres, which directed the cells to assume the same structure as they would in the body. They then put the cells on a chip that could withstand flight and sent it to the International Space Station (ISS) for a week.

When the cells returned to Earth, they exhibited higher activity in genes associated with fat formation, which is linked to muscle degradation. Gene expression related to the functioning of the muscle cells' mitochondria, which produce energy, was also compromised.

"It seems that microgravity is an environment that is accelerating ageing," says Huang.

These changes are more similar to what happens in sarcopenia, or age-related muscle atrophy, than in muscle loss that occurs due to diminished activity, says Huang. When astronauts on the ISS added drugs that can potentially stimulate muscle growth to some of the cells, the genetic activity of those cells was less affected by microgravity (*Stem Cell Reports*, doi.org/m9nk).

This means astronauts and space tourists could potentially mitigate the effects of microgravity by taking certain drugs. The findings could also be useful for studying ageing more broadly, says Huang. ▮

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Comment

On thin ice

The frozen Arctic sea I trekked across to reach the North Pole is melting, creating a potential shipping super-highway. It's very worrying, says **Pen Hadow**

IT WAS 21 years ago that I trekked and swam solo, without resupply, across the icy Arctic Ocean from Canada to the North Geographic Pole. The feat hasn't yet been repeated and probably won't be due to a drop in sea-ice cover caused by warming resulting from greenhouse gas emissions far to the south.

It had taken three attempts over 15 years before success in 2003 in reaching the pole, around 770 kilometres from Canada in the central Arctic Ocean's "high seas". By then, the nature of the 75-day challenge had morphed to require an amphibious element – swimming between drifting ice floes was the only way to get there, with 30 hours in the water in total.

I have spent over 10,000 hours on the Arctic Ocean since 1989, and have been witness to how the region's floating "ice-reef" habitat is dwindling faster than projected.

ELAINE KNOX

My anecdotal experience is borne out by satellite data. NASA reports a decline in the minimum extent of Arctic sea ice – which waxes and wanes seasonally – of 12.2 per cent per decade over the past 40 years. The rise in average ocean surface temperature in the region is four times that seen more broadly, and, in some Arctic sea areas, it is seven times.

The Arctic Ocean could be 85 per cent ice-free in the summer, including at the North Pole itself, from 2035. It could be totally ice-free for nine months each year within another 45 years. The loss of our planet's northern white "cap" – a critically important reflective heat shield – will trigger far-reaching and uncharted consequences for the northern hemisphere and beyond.

As the natural floating barrier of sea ice recedes, new direct impacts, stressors and risks are looming for wildlife from vessel-based activities – commercial fishing, cargo shipping, tourist cruises and deep-sea mining.

Take shipping. Bottlenecks in key routes are creating increasing costs, delays and accessibility challenges. This follows recent geopolitical pressures in the Red Sea affecting the Suez Canal and an unreliable water supply for the drought-hit Panama Canal. For some, Arctic routes might look attractive as the ice recedes.

China intends to operate its "Polar Silk Road" (aka the Transpolar Sea Route), a project to optimise the efficiency of shipping between east Asia and Europe, which involves transiting the Arctic Ocean via the North Pole itself when it becomes ice-free for much of the year. That could be around 6000 km shorter than some non-Arctic routes, making it quicker, more fuel efficient and cheaper.

But all vessel-based activities can be damaging and potentially disastrous for marine biodiversity and its associated ecosystem. They also have a big impact on the circumpolar Indigenous peoples, many of whom depend on local animals for their food and culture.

Explosive surveying techniques, oil tanker spills, commercial-scale fishing and ships hitting marine mammals are oft-cited issues. But worryingly under-reported is the effect on sea life of the noise pollution created by propellers. Marine mammals, for example, have evolved acoustic capabilities to navigate, hunt, socialise and find mates. The impact of ship noise, along with chemical and biological stressors, on some of the Arctic's most charismatic species, including narwhals, orcas and seals, needs to be addressed.

In response, I have set up the 90 North Foundation. Along with Indigenous peoples, scientists, conservation organisations and policy-makers, it will advocate for measures to safeguard the Arctic Ocean's biodiversity. We can't rebuild sea-ice cover in the decades or even centuries ahead, but we can boost the resilience of the biodiversity there by minimising the risks from ships. Establishing an internationally recognised North Pole Marine Reserve to achieve this is our shared goal. ▮

Pen Hadow is an Arctic explorer and ocean conservationist

No planet B

Time for change

The Conservative party's war on the environment cost them dearly in the UK election. Voters around the world support green policies, and politicians should take note, says **Graham Lawton**

Graham Lawton is a staff writer at *New Scientist* and author of *Mustn't Grumble: The surprising science of everyday ailments*. You can follow him @grahamlawton

Graham's week

What I'm reading
I've been bingeing an amazing The Rest is History *podcast series about the fall of the Aztecs. No time to read!*

What I'm watching
Ripley *on Netflix.*

What I'm working on
Prepping for our wonderful science of rewilding weekender in Devon (16 to 18 August). I'm hosting.

This column appears monthly. Up next week: Annalee Newitz

IN MY final column of 2023, I wrote that I hoped this year would see anti-environmental policies being punished at the ballot box. In July, my wish came true, at least in the UK. I was in Mexico City when the results of the general election started to come through, and I watched with glee as 251 Conservative MPs were skittled, ending 14 years of increasingly shambolic rule.

There were many reasons for the Conservative party's defeat, but their regressive, cynical approach to the environment was definitely one of them. And that has given me optimism that similar policies will backfire elsewhere, maybe even in the forthcoming US election.

The Conservatives came to power in 2010 (as part of a coalition) promising to be the "greenest government ever". That didn't last. Not long after, the then-prime minister David Cameron reportedly told his aides to "get rid of all the green crap". From there on in it was downhill.

By the time Rishi Sunak entered 10 Downing Street in 2022 – the fifth prime minister in six years – the government had declared open war on the environment, banning onshore wind farms, rowing back on net zero, promising to "max out" on North Sea oil and gas, jailing green protesters, giving full-throated support to motorists and allowing our rivers to fill with sewage.

This was all done with an eye on the votes of ordinary working people, emboldened by an unexpected victory in a by-election in outer London when opposition to the expansion of the city's Ultra-Low Emission Zone (ULEZ) became an election issue. This led to a widespread belief that pro-environmental policies are a vote loser; the opposition Labour party also fell into this trap.

Two opinion polls published shortly after the election show this was probably a catastrophic miscalculation. One, carried out for the climate think tank E3G, found that the Conservatives made no political gain from ditching the "green crap". If they thought it would woo voters on their right flank tempted by the Reform party, they were wrong. If anything, it damaged them as it made it easier for environmentally conscious Conservative voters – of which there are many – to defect to parties with stronger policies.

The other poll, conducted for Greenpeace, found that in the 251 parliamentary constituencies the Conservatives lost, almost half of voters surveyed said that the party was wrong to backtrack on the environment; less than a third said they were right. The sewage crisis turned out to be a major vote-loser for the Conservatives in their former rock-solid heartlands.

"Trump and Vance have indicated they will take a wrecking ball to Biden's environmental successes"

Polls, schmolls. But the scientific literature has been pointing in the same direction for some time. Voters do support green policies and are willing (in theory) to pay for them.

In February, a team led by Armin Falk at the University of Bonn in Germany published the results of a representative survey of nearly 130,000 people across 125 countries that collectively account for 92 per cent of the global population. They found that 89 per cent of people say they want stronger political action on climate change, and 69 per cent say they are willing to contribute 1 per cent of their personal income to fund such action. "The vast majority of people around the world are willing to act against climate change and expect their national government to act," the researchers conclude.

But interestingly, and pertinently to the Conservatives' misjudgement, people also hugely underestimate their fellow citizens' willingness to act. When respondents were asked how many other people they think are willing to contribute, they said around 43 per cent. Why this could be isn't known. It may have something to do with the media disproportionately giving oxygen to minority anti-environmental views, suggest the researchers.

Whatever the cause, the Conservatives appear to have fallen into the trap of assuming green policies are unpopular when the opposite is true. They should have consulted the scientific literature. But that isn't how right-wing populists operate.

I fervently hope US Republicans have made the same error. Donald Trump and his running mate J. D. Vance are, if anything, even more reckless on the environment than UK Conservatives and have indicated they will take a wrecking ball to President Biden's green successes. They presumably think this burnishes their popularity, but they may be in for a rude shock. Similar research in the US shows that while 80 per cent of the public supports climate action, they wrongly believe that levels of public support are around half of that. Falk's survey found that 70 per cent of Americans believe that their government should do more.

I don't know where I'll be when the US election results start rolling in. Hopefully not the US, because I think there could be trouble. ▮

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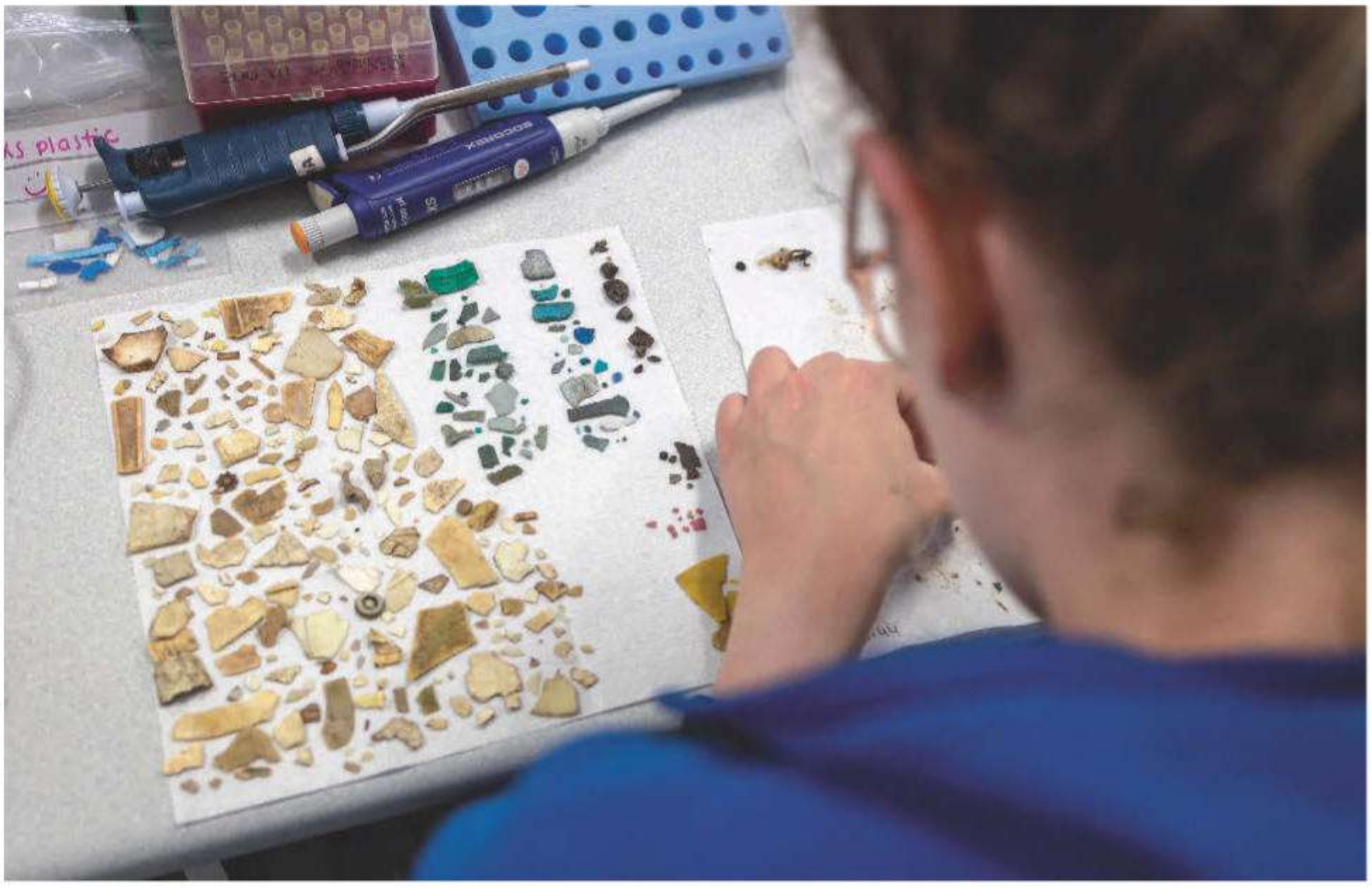
as plastic

Island woes

Photographer Neal Haddaway

POKING out of the Tasman Sea between Australia and New Zealand is a crooked, crescent-shaped volcanic remnant called Lord Howe Island. The rocky isle, which is 10 kilometres long and 2 kilometres across at its widest, is blanketed in a lush, pristine forest and boasts a sandy, coral-rich lagoon.

"It's paradise," says Neal Haddaway, a photographer who went there to document the work of ocean research group Adrift. "The sounds of birds are everywhere, there's beautiful corals, golden sands." Among the bird calls is that of the flesh-footed shearwater (*Ardenna carneipes*), roughly 22,000 of which breed on the island.

But life there is far from idyllic, and newly hatched shearwater chicks, such as the one pictured at top right, are under threat from mounting levels of marine plastic pollution. Adult shearwaters often confuse plastic debris in the sea for food and end up giving it to their young. In fact, Adrift researchers have found that chicks are ingesting increasing amounts of plastic every year. At bottom left, one of the team is sorting out the chunks of plastic found in the stomach of just a single bird.

As a result, these chicks are increasingly underdeveloped, and dozens die from starvation or plastic-related illnesses annually.

"The island may be magical," says Haddaway. "But it's filled with frustration and grief."

To protect this population of flesh-footed shearwaters, which locals affectionately dub mutton birds (see bottom right) after their purported taste, there needs to be tougher legislation against plastic pollution, he says.

Chen Ly

The irresistible rise of RNA

The amazing journey of RNA from background role to star in its own right is told by a wonderful guide who was a big part of the story, says **Tom Leslie**

EZRA ACAYAN/GETTY IMAGES

Book

The Catalyst

Thomas R. Cech

W. W. Norton

FOR 50 years, RNA was DNA's undervalued sibling, but now it has jumped into the spotlight. This multifaceted molecule – which resembles DNA but can morph into a variety of shapes other than a double helix – brought us the most effective covid-19 vaccines and is key to CRISPR gene editing, one of the most powerful technologies in experimental biology.

Yet few of us have an in-depth understanding of the molecule and why it has suddenly become so important for research and medicine. Time for a biography of the rising star, and few could tell the tale more cogently than Thomas Cech, who shared the 1989 Nobel prize in chemistry for discovering that RNA – known mainly as a genetic messenger in cells – also possesses catalytic properties that make it an active participant in the core chemistry of life.

Cech unpacks the story to date in his new book *The Catalyst: RNA and the quest to unlock life's deepest secrets*, starting out by explaining exactly how RNA and DNA "are cut from the same biochemical cloth". Each has a sugary backbone studded with nucleobases. In DNA, these are the familiar A, T, G and C of the genetic code. RNA differs by only a single letter – U in place of T – and its particular brand of sugar has one more oxygen atom, but this makes all the difference. Where DNA is long and stable, RNA tends to be short and volatile, allowing it to pull off wild stunts that make DNA "look like a one-trick pony", says Cech.

In the late 1970s, when RNA first caught his attention, research was largely focused on the more stable sibling. Cech even refers to himself as "a DNA guy". Although RNA had an important role, it was still seen as subordinate, useful only because it shared a language with DNA and could copy its genetic information into smaller "transcripts" that instructed the cell's protein-making machinery. As Cech puts it, RNA was "DNA's grunt".

"Cech keeps us hooked with anecdotes about colleagues or the lab atmosphere after an unexpected result"

But he and his colleague Art Zaug were poised – if unwittingly – to add a new string to RNA's bow. The pair were researching how RNA transcripts formed, and they thought they might catch this as it happened by isolating one from a single-celled organism named *Tetrahymena thermophila*. They became the first to see evidence of RNA catalysing a reaction, something thought to be unique to proteins. This shocker caused a major rethink of the status quo.

This sort of lab work involving test tubes and incubation flasks is hardly glamorous (let alone straightforward to explain), but Cech finds telling phrases and apt metaphors. He also knows how to explain what look like inscrutable decisions by researchers so that by the end of the book, you not only grasp the science, but also how it happened and why breakthroughs occurred when they did.

Take *T. thermophila*. It seems an obscure creature to be the source of such an important discovery – Cech himself called it "pond scum". But he also shows why it was perfect: it has thousands of copies of certain genes, compared with the two or so in human cells. This makes it an ideal organism in which to find transcribed RNA, as the more copies of a gene there are, the more copies of its transcript there are too. It is, says Cech, "easier to find a needle in a haystack if there are 10,000 needles".

This and other breakthroughs laid the groundwork for new uses of RNA, such as in the targeting system that tells CRISPR where to cut DNA or developing aptamers, RNAs that can bind to proteins to show how certain illnesses are progressing. Cech offers meticulous explanations and keeps us hooked with anecdotes about colleagues or the atmosphere in the lab after an unexpected result – all providing just the right amount of breathing space around the science.

The most effective covid-19 vaccines had RNA at their heart

One such moment of levity is his description of geneticist and lepidopterist François Michel, whose bushy beard made him look like he had "just emerged from the forest after a month's-long butterfly hunt".

All this makes *The Catalyst* a joy, from a writer who can't help but be as endearing as he is authoritative. Cech displays a warm appreciation for past students and colleagues, and underlying the book is his passion for science, particularly when driven by curiosity. After all, without the freedom to investigate his "pond scum", he might never have become an RNA guy. ▮

Flying close to the wind

A detailed account of efforts to pull three bird species back from the brink shows the scale of the task, finds **Adam Weymouth**

Book

Feather Trails
Sophie A. H. Osborn
Chelsea Green

WILDLIFE biologist Sophie Osborn has spent a career working with birds that have been a feather's breadth from extinction in the US. Her new book, *Feather Trails: A journey of discovery among endangered birds,* focuses on the Hawaiian crow, the California condor and the peregrine falcon (also found globally). We have pushed them to the brink, and Osborn describes in painstaking detail the Herculean work to pull them back.

Two conflicting feelings arise from reading the book. The first is despair at our mindless destruction of the natural world. Whether it is pesticide use thinning peregrine eggs so they crack prematurely, invasive species killing Hawaiian crows or California condors being poisoned by lead shot, at times it feels like a miracle that we have any birds left at all.

The peregrine falcon, the world's fastest bird, is thriving again in North America – for now

MIKE WALKER/ALAMY

That is tempered with an awe at the ingenuity and tenderness shown in our efforts to save them. The devotion of Osborn and her colleagues leaves you with the feeling that, if we are capable of showing such care to other species, then whatever other damage we have done to the planet might equally be healed.

This is a book for the aspiring field biologist in your life. Describing both the adventure and the impact of her work, Osborn makes it sound the most alluring of career choices. When stories about the natural world feel hopeless, her book shows beyond doubt the difference a truly committed individual can make.

Yet once things unravel, it is terribly hard to stitch them back together. Osborn writes about months spent camping in remote locations, monitoring each released bird during every waking hour, in every type of weather. The time and money expended on each individual animal is immense, and for every hint of progress, there are losses to endure. While such devotion to a few creatures can seem profligate, the truth is that birds will only be saved if we also save their habitat, and they are the emblems that push us to try to restore whole ecosystems. Yes, it would have been so much simpler not to have pushed things to this point. But here we are, and now millions of years of evolution rests in the hands of a few determined people who refuse to take no for an answer.

Some sections of the book are overlong and the extended descriptions of bird behaviour assume a readership as devoted as Osborn. Yet it deserves to be read widely, because it is only in coming to understand these animals, suggests Osborn, that we can choose to love and help them.

We are introduced to the dazzling aerobatics of the peregrine falcon, the world's fastest bird, the playful, sociable Hawaiian crow and the California condor's dedicated parenting. When a species declines to a population you can count on two hands, individuals become personalities, more family member than animal, and Osborn describes each intimately.

Such familiarity makes each setback more heartbreaking. But in the words of ecologist Paul Banko, talking about a failed release of Hawaiian crows in 2016: "There is no room for pessimists in endangered species recovery."

Thanks to conservationists, the peregrine is once again thriving in North America. And after almost 40 years of captive breeding, there are now 347 California condors flying free, although the population still isn't self-sustaining. The Hawaiian crow, however, remains extinct in the wild.

The litany of threats many birds face, from poaching and disease to habitat loss and climate change, means wins are never easy and never assured. Yet the alternative is a landscape empty of birdsong, the hardest thing to endure of all.

Adam Weymouth is the author of *Kings of the Yukon*

New Scientist *recommends*

Tharani Ahillan
Work experience
London

I was given Rutger Bregman's **Humankind: A hopeful history** for my birthday when I was feeling down about the world, and it became my new favourite book. At a time when optimism

HOOPLA

can seem naive, it's good to hear strong arguments for why thinking the best of people is realistic.

Bregman re-examines key moments in history, from the London blitz to the Stanford Prison experiment, questioning what we thought we knew about them. It's a refreshing view, particularly now, when it is most needed.

I also recently visited London's **Hoopla Impro** (pictured) – and I was impressed at the quality of the shows. Amateur actors play a range of "games" using scenarios, words and ideas from the audience, and must make them into scenes.

For someone who hates performing on the spot, it was incredible seeing people live out my worst nightmare and think up great scenes on the fly. A friend was even inspired to sign up for classes themselves afterwards!

The sci-fi column

Uncanny valleys An ordinary-looking town has a secret. If you manage to leave, you will find each successive valley to the east is 20 years ahead. Go west, and the reverse is true. This thought experiment is a heartfelt debut, says **Emily H. Wilson**

Emily H. Wilson is a former editor of *New Scientist* and the author of the *Sumerians* trilogy, set in ancient Mesopotamia. Her second book in the series, *Gilgamesh*, is out now. You can find her at emilyhwilson.com, or follow her on X @emilyhwilson and Instagram @emilyhwilson1

SHUTTERSTOCK/SARATH MAROLI

What if you could visit a valley where your dead loved ones are still alive?

Book

The Other Valley

Scott Alexander Howard

Atlantic Books (UK); Atria Books (US)

Emily also recommends...

Book

The Future of Another Timeline

Annalee Newitz

Orbit Books (UK); Tor Books (US)

If you enjoy time travel twisters, this novel by my fellow New Scientist *columnist – telling the story of a group of time travellers trying to make the future better for women – has all the time travel and twists you could hope for.*

THE Other Valley by Scott Alexander Howard is an unusual and deeply enjoyable time travel novel. It was published early this year, and sadly I didn't review it then for the simple reason that I had no idea it existed. Fortunately, now that I have had it recommended to me and have actually read it, I have special permission from my editor at *New Scientist* to travel back in time and celebrate its publication.

The premise of this superb debut is simple yet complex. We are in a valley not unlike an ordinary valley on Earth. It has a semi-rural, small-town vibe. But there is nothing ordinary here. If you were allowed to walk east over the mountains into the next valley, you would find yourself 20 years into your future. Walk even further, into the valley beyond, and you would be 40 years ahead. Walk on and it would be 60 years, and so on.

Walk west out of your home valley, however, and you would find yourself travelling back 20 years into your past. Walk on further, and you would be 40 years back in time... You get the picture.

If people were free to wander between the valleys, meeting their younger or older selves, collapsing timelines willy-nilly, it would cause a lot of chaos. So the valley we find ourselves in is surrounded by fences, and these borders are guarded by gendarmes.

"If people were free to wander between the valleys, meeting their younger or older selves would cause chaos"

Some foot traffic is allowed, however, on compassionate grounds. Under special circumstances, with the approval of the Conseil, the ruling council, you are allowed to travel into the neighbouring valley that is behind in time so you can view deceased loved ones who are still alive in that valley. This viewing of the dead is carefully policed, since any information leakage between past and present could cause who knows what devastation.

It is a mark of how very good this novel is that I never found myself questioning these elaborate rules and processes, or worrying about the physics of this strange series of valleys or how the Conseil might have come to be. That's because, as well as being beautifully written, *The Other Valley* is a rip-roaring yarn, told with such conviction and elan that I found myself simply accepting the premise and diving right in.

Our hero is a schoolgirl called Odile, and she is 16 when the book opens. Quiet and socially awkward, she is tougher than she realises and her mother wants her to join the Conseil.

If Odile manages to make it through the cut-throat assessment process, a job at the Conseil would give her real power. She would be the one who would decide who can leave the valley. Plus, the job comes with a nice house.

Soon Odile's Conseil prospects are looking good, and her social life also begins to bloom. She is included in a social group and takes the first steps into a relationship with a young man called Edme, a violin virtuoso. But then a chance sighting changes the course of Odile's life forever – and the book takes off with a roar.

I won't say more about the plot because it would be a shame to ruin any of it for you. This is a complicated, jumbo jet of a story, but the author brings it in for its final landing with incredible aplomb, no mean feat when you are juggling multiple timelines and causality.

The Other Valley is a thought experiment, but it is one with huge heart and hope at its core and I do, however belatedly, recommend it to you. ▮

Editor's pick

A ready solution to storing excess renewable energy

Leader, 20 July

From Rick Jefferys, Berkhamsted, Hertfordshire, UK

You are right to highlight the importance of heat storage as a way to use surplus renewable electricity. A big but under-appreciated resource on this front is the hot water tank. We have about 9 million in UK homes, typically supplied from a gas boiler, with a 3-kilowatt immersion heater backup.

Adding an inexpensive Wi-Fi controller to each would enable utility control of 27 gigawatts of demand, 18 times the size of the largest pumped storage scheme in the UK. This would be a lot less expensive than hydrogen storage, yet could absorb most of our peak renewable production.

One big step back to our distant past

20 July, p 13

From David Hulme, Stockport, Greater Manchester, UK

Some things don't change. Our ancient ancestors valued caves as a haven from the weather and wild animals. Now, we are considering using caverns on the moon as protection from space "weather". Perhaps we should think about installing a copy of the Lascaux cave paintings in the first lunar cavern we use for habitation.

These scary aliens aren't even remotely feasible

6 July, p 21

From John Reynolds, Canonbie, Dumfries and Galloway, UK

Having watched the first two *A Quiet Place* films, and reading Douglas Vakoch's lament about the irrational fears raised by the portrayal of scary extraterrestrials in the third film, I wonder if I am alone in believing these blind movie aliens aren't even remotely likely? Sharp-eared enough to hear a picture frame smash a mile away, but not the heartbeat of a person in the same basement? No sonar, but they can get down stairs? Unable to cross water, but space is no problem?

The only credible explanation is that they are a genetically engineered weapon. Given the capabilities of modern robots and artificial intelligence, I would be more frightened of something like this emerging from one of our labs than landing from space.

From David Congleton, Sedona, Arizona, US

The underlying debate is whether it is a good idea to send signals to try to reach intelligent aliens. The worry is there is no global entity that polices such transmissions and, even if there were, it would be impossible to enforce. But I agree with Vakoch that it doesn't matter because aliens advanced enough to pick up those signals will already know we are here by other means.

If in doubt, it is best to stick with whole foods

13 July, p 10

From Norman Fry, Newton Stewart, Dumfries and Galloway, UK

As a scientist, I prefer to think in terms of components, causality and processes. It would be good to know more about these when it comes to ultra-processed foods.

There are many questions. Which additives might degrade the mucus lining of my gut, leaving me at risk of bowel irritation and infections? Which additives could perhaps kill good gut bacteria, affecting my comfort, nutrition and immune system? Which additives might contribute to the sabotage of my body's ability to handle spikes in blood nutrients? Which bulk components of processed foods, by having all their micronutrients removed, are likely to contribute most to harming health through micronutrient deficiency?

Until we have answers, I guess the most sensible strategy is to stick to unprocessed whole foods.

Will roast dodo be back on the menu?

15 June, p 40

From Charles Joynson, Rayleigh, Essex, UK

Bringing back the dodo might have commercial implications because it was apparently tasty to eat. I can imagine meat producers being interested in an edible bird twice the size of a turkey, especially if its growth or reproduction rates could be tweaked.

Maybe sentience can only arise in three dimensions

13 July, p 32

From Wally Sewell, London, UK

In your look at the possibility of extra dimensions, Georges Obied says: "There's no reason why it has to be three. It could have been two; it could have been four or 10."

I wonder whether we can look to the anthropic principle as to why we have at least three dimensions?

It might be a fair assumption that for "observers" such as us to arise, information processors, such as brains, must evolve, and that a likely form for these is logical networks, whereby each node can be connected to any number of others. In two dimensions, to permit connections to all other nodes, connectors – such as synapses or wires – must cross each other. Some sort of gate mechanism, akin to a railway level-crossing, would have to evolve to allow this. Not impossible, but a bit of an engineering challenge!

Could it be that we exist in a three-dimensional universe because three is the minimum number of dimensions in which sentience can easily evolve?

Cosmic significance: A wise man once said...

Letters, 13 July

From Gabriel Carlyle, St Leonards-on-Sea, East Sussex, UK

Andrew Whiteley notes that the idea of our cosmic insignificance involves "equating physical size with significance", which he rightly decries as absurd. A similar point was made by the polymath Frank Ramsey: "I don't feel the least humble before the vastness of the heavens. The stars may be large, but they cannot think or love; and these are qualities which impress me far more than size does."

We need a proper substitute for fuel

20 July, p 36

From Valerie Grant, Stockport, Greater Manchester, UK

As I see it, to replace a lot of fossil fuel use requires a chemical that would react, for example with water, to produce hydrogen on demand. A driver could go to a fuel station with a spent pack of this chemical, buy a new one and fit it in place and drive off in the time it takes to fill up with petrol.

For the record

Geshuang Chen's photo shows an optical corona (13 July, p 25).

To gauge the ideal bowl size for spent pistachio shells, they were modelled as hollow half-spheres with 73 per cent of the packing density of the whole nuts in shells (13 July, p 9).

Boston Dynamics's robots are banned from having weapons such as flamethrowers fitted to them. One used for agricultural research was equipped with a weed-suppressing propane blowtorch (27 July, p 13).

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Becoming human

What is a human and when did such a being emerge? These fundamental questions about ourselves are surprisingly difficult to answer, finds **Colin Barras**

NOELIA DE ALDA

IS IT in the way we live, laugh and love? Or maybe it is our dislike of cheesy clichés? Deep within each of us, there must be something that makes us distinctly human. The trouble is, after centuries of searching, we still haven't found it. Perhaps that's because we have been looking in the wrong place.

Ever since researchers began unearthing ancient hominin bones and stone artefacts, their work has held the tantalising promise of identifying the moment long ago when our ancestors made the transition to become human. Two of the most important fossil discoveries in this quest celebrate significant milestones this year. It is 100 years since the very first "almost human" *Australopithecus* fossil came to light in South Africa, overturning established thinking about our place of origin. And it is 50 years since the most famous *Australopithecus* of them all – Lucy, also known as "the grandmother of humanity" – emerged from a dusty hillside in Ethiopia. Both fossils led researchers to believe we really could identify humanity's big bang: the time when a dramatic pulse of evolution saw the emergence of our human genus, *Homo*.

But today, the story of humanity's birth has become far more complicated. A string of discoveries over the past two decades suggests the dawn of our genus is harder to pin down than we had thought. So why did it once seem like Lucy and her ilk allowed us to define humanity and pinpoint its emergence? Why do we now find ourselves as far as ever from establishing what, exactly, a human is? And what does all this tell us about ourselves?

A century ago, the world's greatest scientific minds were confident that humanity's roots lay in Eurasia. After all, it was in Europe that the first Neanderthal (*Homo neanderthalensis*) fossils had been discovered in the 1820s, and in Asia that the first remains of an even more ancient human – now known as *Homo erectus* – were unearthed roughly 60 years later.

Then anthropologist Raymond Dart at the University of the Witwatersrand in South Africa made a discovery that changed everything. Dart had arranged to receive a consignment of fossils from a South African quarry site now known as Taung. In a crate he opened on 28 November 1924, he found a tiny ancient skull with a mix of ape-like and human-like features. He soon concluded that it represented an extinct genus of "pre-human stock". Dart named the genus *Australopithecus* and placed the fossil – nicknamed the Taung Child – in the species *africanus*.

The roughly 2.8-million-year-old Taung Child was important for two reasons. First, it suggested that our evolutionary roots lay in Africa rather than Eurasia, prompting further investigations in South and East Africa and the recovery of more hominin fossils. Second, it gave us an idea of what our pre-*Homo*

ancestors looked like. However, it still wasn't clear exactly which species of *Australopithecus* gave rise to *Homo*, or when this immediate ancestor had lived.

Then along came Lucy. Still arguably the most famous hominin fossil of them all, Lucy is a roughly 40 per cent complete *Australopithecus* skeleton. "It wasn't a single bone or part of a skull. There was an image people could identify with and see that this was an individual," says Donald Johanson at Arizona State University, who unearthed Lucy in the Afar region of Ethiopia almost 50 years to the day after Dart first held the Taung Child (see "Finding Lucy", page 35). Just like Dart, Johanson knew instantly that this was a great discovery.

The first thing that made Lucy special was that she wasn't alone. Johanson and his colleagues unearthed bits and bobs from dozens of ancient hominins during their Ethiopian fieldwork, providing a rare opportunity to study an ancient hominin

"Something momentous seemed to have occurred at the dawn of *Homo*"

population, not just an individual. "Those are the studies that lead to major advances in palaeoanthropology," says Johanson's colleague Tim White, now at the University of California, Berkeley. Together with the late Yves Coppens, they eventually concluded that all the fossils at the site represented a single species, which they named *Australopithecus afarensis*.

The second outstanding thing about Lucy was her pedigree. Johanson and his colleagues declared that *A. afarensis* occupied a key place in our evolutionary tree: here, at last, was the species that gave rise to our genus, *Homo*. "It was a pretty bold assertion," says Johanson. Yet it became accepted by many researchers, even though, at 3.2 million years old, Lucy predated the Taung Child. That the older species, *afarensis*, should be considered the grandmother of humanity rested in large part on Lucy's anatomy. Dart's research left no doubt that *Australopithecus* was more ›

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ape-like than *Homo*. But the Taung Child and other *A. africanus* individuals had some features of the face and skull indicating that the species had evolved in a direction distinctly unlike that of our own genus. *A. afarensis*, by contrast, had none of these evolutionary specialisms. It was anatomically more primitive, making it a great starting point from which to evolve a *Homo*-like body. This was assumed to have happened around 2.9 million years ago, because that is when *A. afarensis* went extinct.

One great leap?

This idea had broader implications. Given that *A. afarensis* was so primitive compared with the species in our genus, it suggested something momentous must have occurred at the dawn of *Homo*. "We thought there was this huge change from these ape-like australopiths to these tall and elegant human-like creatures striding across the savannah," says Carol Ward at the University of Missouri.

There was even a good explanation for such a dramatic evolutionary event. For decades before the discovery of Lucy, researchers had uncovered stone tools alongside the remains of ancient hominins. But with *A. afarensis*, there were none. "And boy, we certainly looked for them," says Johanson. It seemed that *A. afarensis* represented a pre-tool stage of our evolution. This suggested that stone tool technology was a *Homo* innovation, useful for killing and butchering animals and allowing *Homo* to adopt a meaty diet that contrasted with the plant-rich diet of *A. afarensis*. "There was this assumption that several things went together in an evolutionary package," says John Hawks at the University of Wisconsin-Madison. "Stone tools, new diets, smaller teeth and bigger brains." This set of features defined *Homo*, and by extension, it also defined the moment our ancestors became human.

However, in the past 20 years, the sharp dividing line between *Australopithecus* and *Homo* has begun to blur. In 2019, Jessica Thompson at Yale University and her colleagues brought the evidence together. One key point is that *A. afarensis*'s brain, while small compared with ours, was still 30 per cent larger than those of chimps of a similar size, suggesting Lucy's species had a calorific diet. Furthermore, its hands were surprisingly human-like, perhaps indicating dexterity. This would fit with recent evidence of cut marks on ungulate bones, suggesting these hominins used stone tools to butcher animals around 3.4 million years ago.

Much of this research remains controversial: White, for instance, has argued that the supposed cut marks are scratches left by crocodile teeth. But Thompson thinks that, collectively, the evidence makes a persuasive case that several traits we had thought unique to *Homo* were seen in *Australopithecus*. At a symposium this year to mark the 50th anniversary of Lucy's discovery, she suggested that *A. afarensis* might have been a scavenger, targeting animal carcasses and using stone tools to smash open the bones to access the nutritious marrow overlooked by flesh-eating carnivores.

Another recent finding also challenges the idea that hunting is what set *Homo* apart. A study published last year suggests that *Paranthropus*, a genus of strange, heavily built hominins that evolved at the same time as *Homo*, also used stone tools to butcher animals. This indicates that there were fewer differences than we thought between the two contemporary genera. In light of all this, researchers now question whether there really was a dramatic transition between *Australopithecus* and *Homo*. "We no longer assume there was an evolutionary package," says Brian Villmoare at the University of Nevada, Las Vegas.

In retrospect, this makes sense. *A. afarensis* is astonishingly well represented in the fossil record, but its disappearance some 2.9 million years ago coincides with a million-year period in which the hominin fossil record is patchy. By the time things improve, species that looked and behaved more like we do had appeared. It was easy to assume that those anatomical and behavioural changes had all occurred in one dramatic evolutionary event around 2.9 million years ago. In reality, they probably happened gradually throughout that million-year interval, says Villmoare.

So, what does this mean for our attempts to define when humans evolved? One radical idea is that the term "human" should expand to include every hominin that emerged following the split between our ancestral line and chimps some 7 million years ago. Although popular in the mid-20th century, few researchers favour this view today. However, more recently it has been argued that since the average lifespan of a primate genus is between 7 million and 11 million years, even chimps and bonobos should count as human. At the other extreme is the idea that our ancestors became truly human only after our ancestral line diverged from that of Neanderthals around 800,000 years ago. This rests on the assumption that Neanderthals were brutish and unintelligent. However, following recent archaeological and genetic discoveries, many now argue that there

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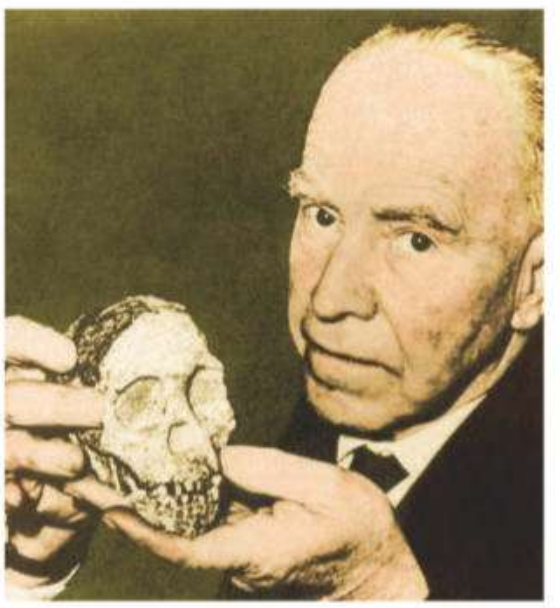
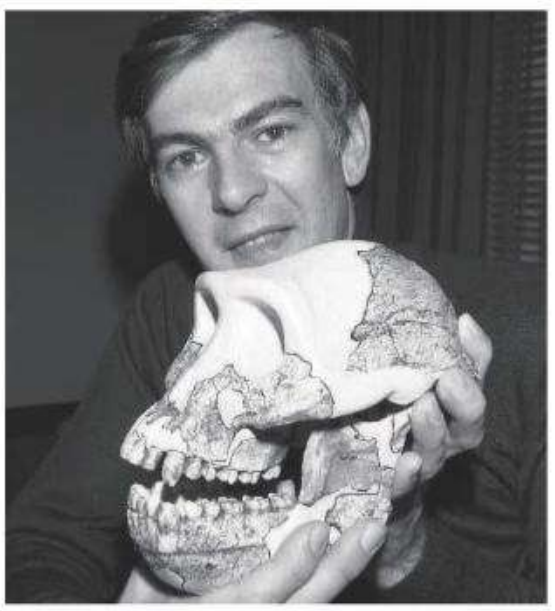


SCIENCE HISTORY IMAGES/ALAMY

The Taung Child, discovered by Raymond Dart a century ago, isn't as old as Lucy but is less likely to be a direct human ancestor



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It is 50 years since Donald Johanson found Lucy, the fossil dubbed the "grandmother of us all"

were few behavioural differences between our ancestors and them. "There's a sense in which 'becoming human' can no longer be accounted for by events of the past few hundred thousand years," says Hawks.

Walking the walk

Today, ideas about how to define "human" tend to fall into two camps, one based on behaviour, the other on ancestry. In the former is Bernard Wood at the George Washington University in Washington DC. "When we're searching for the origin of *Homo*, we are searching for the first evidence of creatures that go about their lives as we do now," he says. *Australopithecus* probably didn't. Even if we accept that *A. afarensis* butchered animals, it had the long and powerful arms of a hominin that spent a fair amount of time climbing in trees – something that humans, in general, don't do. Moreover, some species of *Homo*, including *Homo habilis* and *Homo floresiensis*, also had long and powerful arms, leading Wood and his colleague Mark Collard at Simon Fraser University, Canada, to suggest that we reassign them to *Australopithecus*. They argue that *Homo* began only once hominins grew longer legs and became confined to the ground – a stage that was reached with the evolution of *H. erectus* around 2 million years ago.

Researchers in the other camp include Villmoare, who says genera should be based solely on evolutionary grounds. Do this using the conventional hominin family tree, and *Homo* is actually easy to define. This is because the descendants of *A. afarensis* ultimately went down two distinct evolutionary paths: *Paranthropus* and *Homo*. Villmoare says this fork in the road, which happened roughly 2.9 million years ago, represents the moment that both genera came into existence. Regardless of the way they looked or behaved, all hominins on the first path belong in the *Paranthropus* genus and all those on the second path belong in *Homo*. However, this assumes that the conventional hominin family tree is correct – which it might not be. "There have always been uncomfortable questions surrounding the genus *Paranthropus*," says Ward. She suspects that it includes hominins that are superficially similar in appearance but not closely related. If so, that convenient fork in the road after *A. afarensis* becomes less clear, and ancestry isn't such a simple way to define what counts as human after all.

"Some think even chimps and bonobos should count as human"

A century after the discovery of the Taung Child, and 50 years after Lucy, we seem no closer to understanding when or why humans emerged. That is frustrating, but also, paradoxically, a reflection of how much progress has been made. When researchers had just a handful of hominin fossils to work with, it was easy to spot the significant differences between them and to assume that there was a dramatic moment when our ancestors became human. It is because we have better evidence that we now know things are more complicated.

What is clear is that we didn't suddenly "become human" 2.9 million years ago when *A. afarensis* died out. That should come as no surprise. Evolution is a continuous process, and the propensity to divide life up into conspicuously distinct species and genera is less a reflection of fact than another human idiosyncrasy. Ultimately, where we draw the line between "us" and "them" isn't simply a biological question – it is a philosophical one too. ▮

Colin Barras is a freelance writer based in Ann Arbor, Michigan

Finding Lucy

When Donald Johanson took his first field trip to Africa in 1970, most of the best-known hominin fossil sites there contained geological deposits stretching back no further than 2 million years. But humanity's origins predate this. "I thought 'there must be other places to look'," says Johanson, now a palaeoanthropologist at Arizona State University.

He soon met the late Maurice Taieb, a French geologist who had begun exploring Ethiopia's Afar region. Taieb's photographs revealed a landscape littered with animal fossils that were more than 3 million years old. "If human fossils could be found at a place like this, it would open up a significant new vista on our origins," says Johanson.

It turned out that they could. Several hominin fragments had already been unearthed before Johanson discovered the partial skeleton of a small individual on 24 November 1974. "My girlfriend at the time, [team member] Pam Alderman, said if you think it's a female, why don't we call it Lucy, after [The Beatles's hit song] *Lucy in the Sky with Diamonds*?" says Johanson. "I wasn't that enthusiastic: I thought she deserved a scientific name." Eventually, she got one, *Australopithecus afarensis*. But it is as Lucy that she became a global celebrity.

SABENA JANE BLACKBIRD/ALAMY

FIRST LIGHT

The earliest stars changed the course of cosmic history. We are finally on the verge of seeing them, says **Stuart Clark**

AS TURNING points in cosmic history go, the birth of the first stars is hard to beat. When they flickered into existence between 200 and 400 million years after the big bang, the energy pouring from them ripped apart the atoms of gas that had been cooling the universe, reheating them in a process called re-ionisation. Then, as they burned and died, they created a cocktail of chemical elements that primed the universe to generate galaxies, planets and, ultimately, life itself.

No wonder astronomers have been itching to glimpse this first stellar generation. They were spectacular, for starters. Huge and ferociously bright, they are thought to have been up to 300 times as massive as our sun and 10 times hotter. But observing them could also tell us a lot about the mysterious early phase of the universe, not least how it became potted with supermassive black holes in what seems like an impossibly short time.

Now, we might finally be on the cusp. Earlier this year, astronomers reported that the James Webb Space Telescope (JWST), by fixing its superior vision on the outer reaches of a very distant galaxy, may have already seen evidence of the first stars. "The observations we can do now are really pushing our knowledge," says Hannah Übler at the University of Cambridge.

That signal may turn out to be a false alarm. But what's exciting right now is that others are homing in on different signatures of the universe's early light. There is even some suggestion that the first stars might be hiding closer to home than we ever thought possible.

To understand the allure of the first stars and how we might identify them, it helps to know that stars in general are intimately connected to the chemical composition of the universe. The big bang created only the two lightest elements, hydrogen and helium (plus traces of lithium and beryllium). All the heavier elements – like the oxygen we breathe, the iron we mine, the silver we prize – were made in the hearts of stars, where nuclear fusion glued subatomic particles together to form larger atoms. As stars died and exploded, they spread these elements across the universe, only for them to be incorporated into new stars, which made heavier and heavier elements. It is true what they say: we are made of stardust.

Primordial giants

Astronomers split the stars we have detected so far into two types. Population I stars, such as our sun, are the youngest and contain the highest proportion of heavy elements. Population II stars are older and contain fewer heavy elements. But it stands to reason that there must be a third type: the very oldest stars that are made exclusively from hydrogen and helium. These are the population III stars.

Today, if a star grows to be more than say 100 solar masses, it will produce so much internal energy that the pressure will lift off its outer layers and blow them into space. This places an upper limit on the mass a modern star can attain. Not so with population III stars. The lack of heavier elements means that outward pressure doesn't kick in so strongly. "If a population III star forms massive, it stays massive," says Simon Glover at the University of Heidelberg in Germany. Based on these assumptions, astrophysicists have long thought the majority of the first stars would have been giants, typically hundreds of times heavier than our sun.

The lack of heavy elements also means the first stars would have had to become denser and hotter to generate the energy necessary to remain stable by preventing collapse. The hotter and bigger a star, the shorter its life. So astronomers reckon the first stars would have lived fast and died young – lasting perhaps only 5 million years. If that's true, then the first stars must all be long dead. Still, in astronomy, looking at extremely distant objects equates to peering back in time, because of how long it takes their light to reach us. So although seeing one of the first stars is fiendishly difficult, it isn't out of the question.

One reason scientists are so keen to do it involves the puzzle of supermassive black holes, which have masses spanning from a million to billions of times that of the sun. We know that one of these monsters lies at the centre of almost every galaxy. How do they get there? Well, when the first stars exploded and died, they would have spread their outer layers into space, with the remaining mass collapsing into black holes, each weighing between 10 and 100 solar masses. These baby black holes presumably collided with each other over time and fed off passing stars and gas clouds, gradually growing into the supermassive black holes we see today.

But there is a problem. The further back into cosmic history we have looked, the more astounded we have been to see nigh-on fully formed galaxies and supermassive black holes that shouldn't exist because there hasn't been enough time for them to form. "It is one of the big mysteries at the moment: how do you make very massive black holes very early in the universe?" says Glover.

He thinks it could be telling us something new and extraordinary about the first stars, and he isn't the only one. A number of teams have been looking again at their computer models and getting a surprise: it is possible ›

AKINBOSTANCI/GETTY IMAGES

that as re-ionisation increased the temperature of the gas in the universe, these hotter clouds collapsed into single stars with extremely high masses. Rather than hundreds of solar masses, we are talking about a few tens of thousands of solar masses. "These may give you a pathway to making some of the first very massive black holes," says Glover. That's because they would accumulate so much mass that after their brief stint as a hyperluminous star, they would collapse directly into a black hole. But to prove this idea, we need to find the stars and see what they were really like.

There is a way to do this, in principle. It involves a technique called spectroscopy, which means measuring the intensity of a range of wavelengths of light. Different elements absorb specific wavelengths, so spectroscopy gives us a fingerprint-like reading for a star, showing exactly which elements it contains and how much of them are present. Since the 1950s, scientists have been conducting spectroscopic surveys of the sky, looking for stars with negligible amounts of heavy elements. They have certainly found some very old stars, but none that makes the cut as a bona fide member of population III.

Sadly, not even JWST – which was specifically designed to look as far into the distant universe as possible – can see population III stars directly. The good news, though, is that it might just be capable of spotting them through their effects.

The intense radiation these stars emitted had the power to illuminate surrounding gas clouds and strip all the electrons from the helium atoms found there, creating helium II ions. Some of these electrons then recombine with their parent atoms, creating a glow. Since the glowing clouds of gas are vast compared with the stars, they should be much easier to see. And it is these clouds that Übler and her colleagues think they have detected.

Working with Roberto Maiolino at the University of Cambridge and others, Übler used JWST's Near-Infrared Spectrograph instrument to study a distant galaxy whose discovery was originally reported in 2016. This galaxy, GN-z11, was at that time the most ancient ever seen, at 13.4 billion years old. That made it a prime candidate to have population III stars nestled in its halo, the outer reaches of the galaxy where primordial gas would gather.

When the researchers got their hands on the data for GN-z11, they found some tentative evidence of helium II close enough to the galaxy for it to have been in the halo. They applied for more time on JWST and got it, resulting in a more careful look at the GN-z11's environs. Their results, published this year, revealed more widespread indications of helium II. Could they have found the smoking gun of population III?

Maybe. But just because a population III star could produce this signal doesn't mean that is what we are seeing. There could be other explanations. "There's a relatively nearby galaxy, I Zwicky-18, which has a lot of very ionised helium, but we don't think it's coming from population III stars," says Glover. Instead, the ionising radiation there is thought to be the result of gas being pulled from a star onto either an incredibly dense neutron star or a black hole. In other words, being sure that the glowing gas is caused by a population III star will hinge on eliminating other explanations.

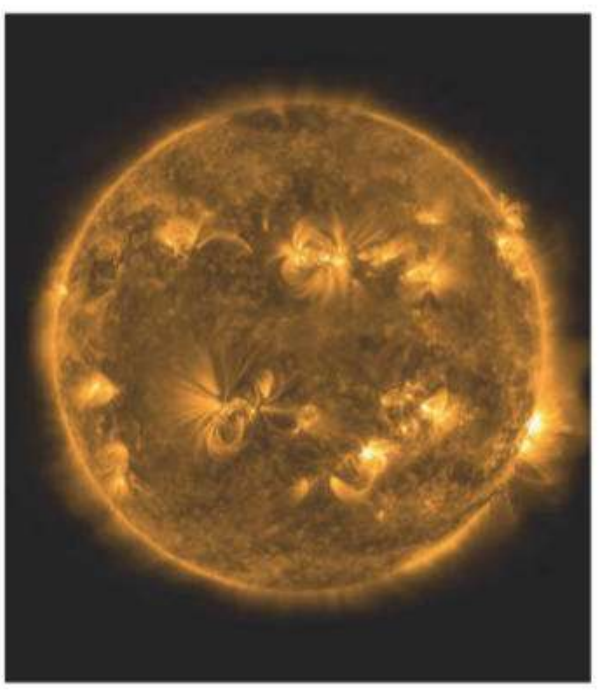
Maiolino knows this all too well. "That's why we are still saying that this is a tentative result," he says. To try to definitively establish the source of the ionising radiation, he and his colleagues have been awarded another 40 hours of coveted time on JWST to spend solely on this source. The observations have been scheduled for May 2025 and are designed to pick up even the faintest traces of heavier elements. If they see them, it would suggest that a population III star isn't responsible. If not – it could be a slam dunk. "We are really pushing Webb to the limit," says Maiolino.

But Übler and Maiolino's method isn't the only tool at our disposal. Rudrani Kar Chowdhury at the University of Hong Kong and her colleagues recently proposed that we could look for the exceedingly luminous flares emitted by population III stars as they are torn apart by black holes, a process known as a tidal disruption event or TDE. "JWST is discovering massive black holes [in the very distant universe] and also massive galaxies. That made us think about a [population III] star getting captured by the massive black holes," says Chowdhury.

When a star is pulled apart by a black hole, it can release more mass than the black hole can easily swallow. This sets up an incredibly turbulent environment, in which the star's gas heats up and glows. When this happens to a population I or II star, the radiation interacts

"The first stars could have been about 300 times the mass of our sun"

If modern stars like our sun got too big, their atmosphere would start to blow away



J MARSHALL – TRIBALEYE IMAGES/ALAMY

NASA, ESA, P. OESCH (YU), G. BRAMMER (STSCI), P. VAN DOKKUM (YU), AND G. ILLINGWORTH (UC SANTA CRUZ)

Galaxy GN-z11 (inset), where astronomers may have spotted signs of primordial, population III stars

with the heavier elements and drives a stellar wind that cools the remaining gas, allowing it to settle into the black hole. But, in theory, the lack of heavier elements in the population III stars should prevent these cooling flows, and so the gas stays hot and luminous for longer.

This means that the luminosity and duration of a TDE flare, known as its light curve, can be tied to the mass, density and heavy element content of the star being pulled apart. "So, if we can detect some light curves from this kind of massive stellar TDE, then we can extract the properties of the population III stars," says Chowdhury.

Seeing these events won't be easy. While they are within the detection limits of JWST – and NASA's forthcoming Nancy Grace Roman space telescope – the team calculates that such events would be rare and fundamentally unpredictable. This will give Roman the edge because it is designed to survey a larger swathe of sky. "Compared with JWST, Roman has 100 times the sky coverage, so that gives a higher chance of detections," says Chowdhury's colleague Janet Chang, also at the University of Hong Kong.

But there is one final twist to this story. While most astronomers continue to focus on the very distant universe in their hunt for population III stars, others have begun to suspect that there may be some survivors from that primordial epoch in our cosmic backyard.

The first models of the initial population III stars, the ones that began the process of re-ionisation and reheating the gases in the universe, suggested that the stars would all weigh in at hundreds of solar masses. Over the past decade, however, advances in computing power have allowed astronomers to execute more sophisticated simulations. These show that the first models might have neglected the effects of rotation on the collapsing gas cloud that became the star, especially when it comes to slightly cooler clouds of gas.

As a relatively cool gas cloud collapses, it naturally flattens into a disc – think of a pizzaiolo twirling dough. This means not all of the cloud's initial mass ends up in the central star. Instead it fetches up in the surrounding disc, where it fragments into smaller population III stars. "We no longer think that you just form one massive star. You actually probably get a wide range of stellar masses dominated by massive stars," says Glover.

A few of these stars could have been really tiny, perhaps as small as half the mass of our sun. As we already know, a star's mass correlates inversely with its lifetime, so we would expect these meagre celestial spheres to eke out their supply of nuclear fuel for tens of billions or even trillions of years. "If population III stars are produced with masses below 0.8 or 0.7 solar masses, then these stars live longer than the age of the universe. So every single one of these stars should still be around," says Ralf Klessen at the University of Heidelberg.

There is even reason to think that some of these stars could be lurking close at hand. In 2018, we saw the most pristine star yet detected through spectroscopic sky surveys. Called SMSS J1605-1443, it has just one-millionth of the iron present in the sun and is located in the Milky Way's halo. This can't be a population III star – it is more likely to be a direct descendent – because it still contains some iron and, strangely, has a relatively large amount of carbon. We don't fully understand this star's unusual composition. But it is a sign that very old stars might not look exactly as we expect them to – and they can be found nearby.

On top of that, a recent study of a catalogue of stars compiled by the European Space Agency's Gaia mission has revealed 200,000 Milky Way stars that appear to be extremely lacking in heavier elements. That gives us an awful lot of targets. One way or another, you can't help wondering if we will glimpse the universe's first lights much sooner, and much closer, than anyone previously imagined. ▮

Stuart Clark is a consultant for *New Scientist*. His latest book is *Beneath the Night*

Mind merge

Brain implants that give people with paralysis the ability to walk, talk and operate computers with their thoughts are advancing rapidly, but will they one day let us compete with an artificial superintelligence, asks **Ingrid Wickelgren**

A CYBORG bested me. When I played the online game WebGrid, using my finger on a laptop trackpad to click on squares appearing unpredictably on a grid, my speed was 42 squares per minute. When self-described cyborg Noland Arbaugh played it, he used a chip embedded in his brain to send telepathic signals to his computer. His speed? 49.

Arbaugh was paralysed from the neck down in 2016. In January, he became the first person to be surgically implanted with a chip made by Neuralink, a company founded by Elon Musk. Since then, Arbaugh has been operating his phone and computer with his thoughts, surfing the web and playing *Civilization* and chess.

But Neuralink isn't the only outfit melding human minds with machines using brain-computer interfaces (BCIs). Thanks to a series of trials, a growing number of people paralysed from spinal cord injuries, strokes or motor conditions are regaining lost abilities. The successes are taking some researchers by surprise, says neurosurgeon Jaimie Henderson at Stanford University in California. "It's been an incredible ride."

Where that takes us remains to be seen. Musk recently mused about making a bionic implant that will allow us to compete with artificial superintelligence. Others are contemplating more profound implications. "In the future, you could manipulate human perception and memories and behaviour and identity," says Rafael Yuste at Columbia University in New York.

But while BCIs are undeniably impressive, as Arbaugh's WebGrid score demonstrates, the relationship between brain activity, thoughts and actions is incredibly complex. A future in which memories can be implanted and skills downloaded is enticing, but there will be incredible challenges to overcome.

BCIs work by first detecting electrical signals from neurons using metal discs, wires or electrodes that are either inserted into the brain, under the skull or placed over the scalp. This information is then sent to a computer, where it is processed and translated into commands that, for example, enable a person to type a sentence or control a robotic device.

Decoding thoughts

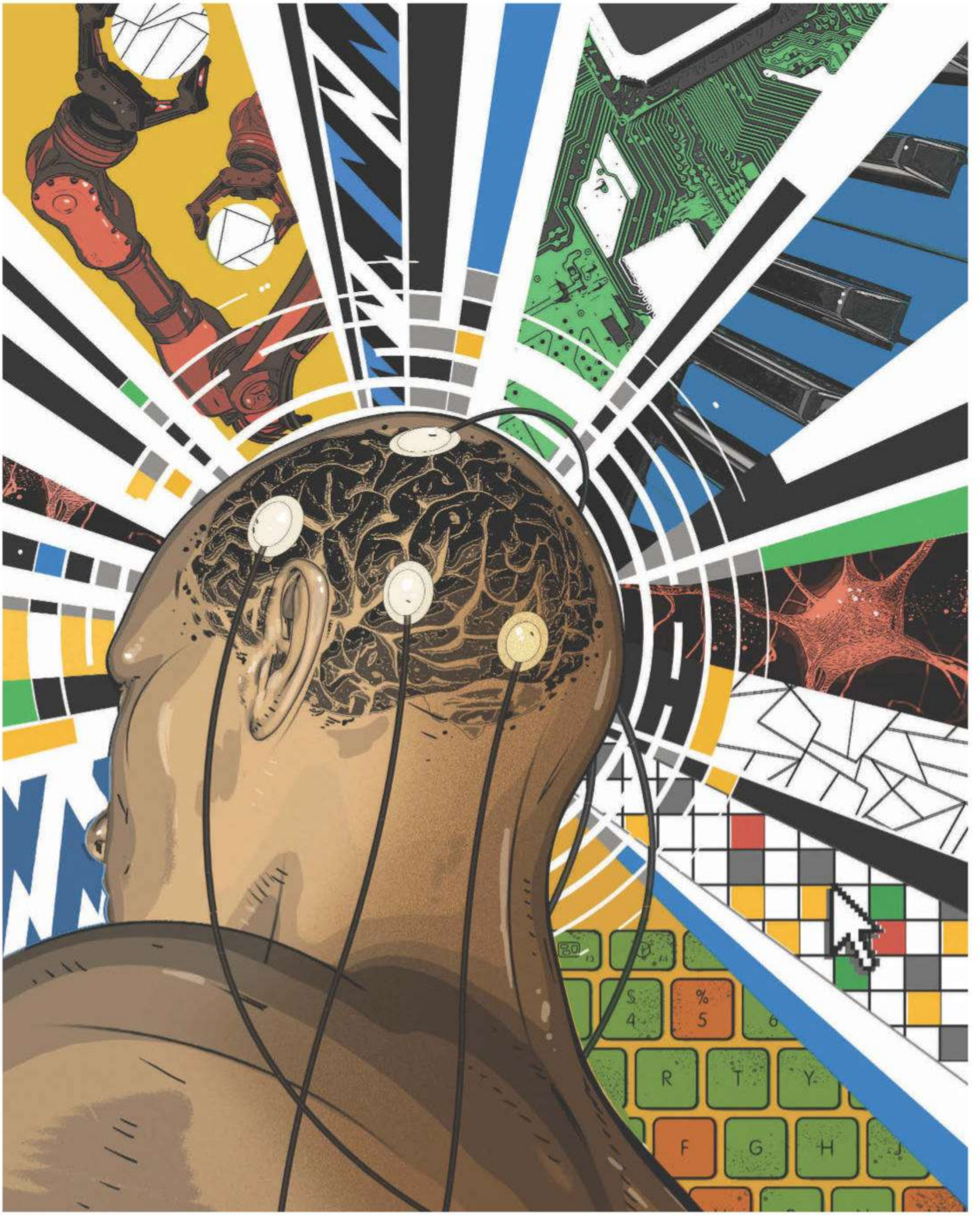
We have been able to siphon data from the brain in this way for decades. In 1998, researchers implanted the first invasive BCI, consisting of two electrodes, into the brain of a builder named Johnny Ray who had become almost totally paralysed after a stroke. Ray learned to tune the signals from his implant to slowly spell words by imagining moving his hand to move a cursor over letters on a keyboard. But the functionality and reliability of such early BCIs was poor. Typically, these devices took weeks or months of training before they could be used. Even then, they only allowed people to select a few characters per minute and were prone to errors.

One issue was that devices made of only a few electrodes didn't gather enough data. There are billions of intricately connected neurons in the human brain, and research had begun to indicate that it is the patterns of activity in groups of neurons – not single cells – that specify our thoughts, actions and perceptions. To decode these patterns, BCI researchers wanted to test and deploy technology that would pick up the individual signals of many neurons at once.

To enable this, they began working to adapt a technology originally invented by Richard Normann at the University of Utah to stimulate the brain's visual cortex to restore sight. Normann's 4-millimetre-square chip, called the Utah array, was studded with about 100 microelectrodes that could penetrate the outer layer of the brain. The array was redesigned to track the firing of individual neurons, and each array could record from about 100 of them at once. "That gave us the ability to look at populations of neurons and see really rich signals," says Carlos Vargas-Irwin at Brown University in Rhode Island, who began working with Utah Arrays as a college student in 2000. The collective output of these populations represented the brain's language, guiding functions such as reaching, writing, walking, talking, smiling and thinking – and it was ripe for interpretation.

The signals most relevant to devices for people with paralysis reside in the motor cortex, a strip of tissue that wraps like a headband across the top of the brain and is charged with planning and executing movements. It is roughly organised by body part. For instance, in its face region, there are neurons that control face muscles, and in the leg region, there are neurons that operate the legs, and so on. BCI researchers often put electrodes in the hand region because people tend to find it easy to imagine moving their hands to do useful things, such as type or manipulate a joystick or robotic arm.

In 2004, researchers at BCI consortium BrainGate reported implanting Utah arrays in people with paralysis. One by one, people ›



CHRIS MALBON

JIMMY RAVIER

volunteered for brain surgery, moving the field forward. A man with a paralysed upper and lower body due to a knife wound used his thoughts to direct a cursor, opening simulated emails and operating a television, as well as opening and closing a prosthetic hand. Two people who had the same sort of paralysis following strokes telepathically manipulated a robotic arm to reach and grab objects; one of them drank coffee from a bottle. A woman with muscle weakness due to amyotrophic lateral sclerosis, a neurodegenerative condition that leads to paralysis, directed a cursor towards up to eight targets on a screen.

"Every time we do one of these types of surgeries and work with a participant, we learn so much," says Henderson, who is part of BrainGate and also an adviser for Neuralink, in which he has equity.

In the past few years, the capabilities of experimental devices that translate brain activity into movement and even speech have surged ahead, says Yuste. With ever-more powerful algorithms at their disposal, researchers can decipher the meaning of increasingly complex patterns of activity from groups of neurons. "There is starting to be wholesale access to brain processes," says Yuste.

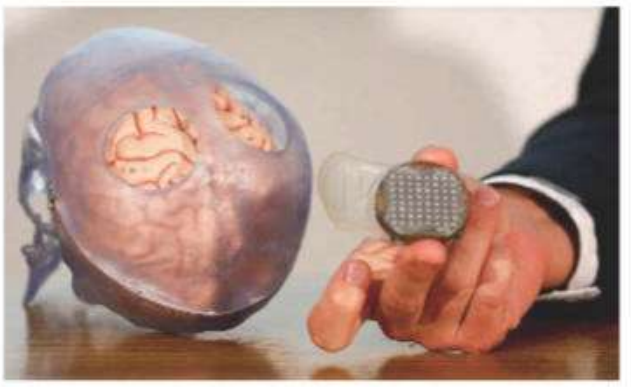
In 2021, it was reported that Dennis DeGray, whose spinal cord was severed in a bad fall over a decade earlier, set a new speed record for virtual typing enabled by a Utah Array of 90 characters per minute. Unlike Ray and his bionic descendants, who moved cursors by thinking broadly about moving a hand, DeGray "typed" by visualising himself writing on a legal pad, so his brain fired off signals for the fine, multi-joint movements that would have been required for this. An AI tool then decoded the neural signals of this imagined handwriting and mapped it to individual letters.

Similarly, in unpublished work, Vargas-Irwin and his colleagues say they have ferreted out the brain's "codes" for dozens of hand gestures as well as individual finger movements involving both hands at the same time. In research presented by Vargas-Irwin in 2022, a man paralysed from the neck down who has two implanted Utah arrays played a simulated piano with 10 keys by imagining moving specific fingers on either hand. It doesn't allow him to play anything by Tchaikovsky just yet – more like *Mary Had a Little Lamb*, says Vargas-Irwin. "But it has been proof of concept that they can control each finger independently."

In one of the most astounding developments, BCIs have emerged that can reanimate paralysed limbs themselves. Last year, Grégoire Courtine at the Swiss Federal Institute of Technology in Lausanne and his team reported using a less invasive "electrocorticography" array sitting under the skull just above the leg regions of the motor cortex, without penetrating brain tissue, along with AI to read signals in the brain and relay them to a stimulator in the spinal cord. This enabled Gert-Jan Oskam, whose legs are paralysed, to stand and walk – even navigating stairs and uneven terrain. "[We have built] a digital bridge that turns the thought into action," says Courtine.

Moreover, the patterns of activity identified by AI are challenging our understanding of the brain. On a more basic level, work on BCIs has revealed that the jurisdictions of groups of motor cortex cells extend beyond single body parts to multiple joints and multiple body parts. It was found that DeGray's array, despite being placed in the "hand area" of the motor cortex, could also pick up patterns for the movements needed to produce speech. "We had him speak and, to our great surprise, there were pretty strong signals for words and syllables in an area of brain that we thought was pretty highly specialised for hand function," says Henderson.

This and other discoveries led to a more nuanced understanding of the brain region charged with orchestrating actions. Instead of being dedicated to one body part, as, say, a cardiologist might focus on the heart, motor cortex neurons seem to be more like general practitioners with a subspeciality. "Even in one patch of [motor] cortex, you can get some information about what the entire body is doing – so arms, legs, face, tongue. There's echoes of all that information," says Vargas-Irwin. This suggests that the motor cortex is organised according to complex concepts, such as actions, rather than body parts.



REUTERS/EMMANUEL FOUDROT

Arrays (top) can transmit data in and out of the brain to control objects like exoskeletons (above)

Still, the hand region is the wrong place to put a BCI if the primary goal is to produce speech. Last year, it was reported that a woman named Ann Johnson, who had lost her ability to speak following a stroke, used an electrocorticography array to operate an avatar on a computer near Johnson that spoke for her at 78 words per minute. The avatar's AI-generated voice was trained on recordings of Johnson's voice made before the stroke and made life-like movements of its mouth. It could also display facial expressions such as happiness, sadness or surprise based on readings from the array whenever Johnson

Gert-Jan Oskam, who was paralysed in a cycling accident, is able to walk using a brain-computer interface

REBECCA NOBLE/NEW YORK TIMES/REDUX/EYEVINE

Noland Arbaugh is the first person to have a Neuralink chip implanted in his brain

tried to produce the facial expressions related to these emotions. "We are looking at Ann's embodiment in that digital form," says neurosurgeon Edward Chang at the University of California, San Francisco, who led the study.

After seeing Johnson's avatar in action, Chang was astounded by what his team had done. He called Yuste in the middle of the night to talk about the implications. Had technology effectively expanded the boundaries of our bodies and minds? "It's not moving a cursor or playing a video game," he says. "This is another level where you are looking at an embodied form of yourself."

Henderson's team, among others, is attempting to expand this ethereal communication to inner speech, as a way of understanding how thoughts become communications. "One can start to see how conceptual info is represented throughout the brain," he says. One day, this understanding might lead to devices that can restore speech in people who, after a stroke, say, have an idea to express but can't put it into words. It also comes closer to truly reading a person's mind. "If you have the means to map and manipulate brain activity, by definition, you can map and manipulate mental activity," says Yuste, who sees few limitations to the near-future possibilities of BCIs.

Universal implant

Engineering challenges still dog the field. Brain-embedded devices, like the Utah and Neuralink arrays, pick up brain activity more precisely but can lose their signal quality over time. Meanwhile, some BCI set-ups involve wires which sprout from ports that present a persistent infection risk, and most eventually have to be removed or replaced.

These troubles aside, truly melding human minds with machines, as Musk envisions, will require a two-way stream of information that both reads from and writes to "every aspect of your brain", Musk said in a Neuralink Show and Tell in 2022.

There has been gradual progress on that front. In 2021, a study reported on a man with a spinal cord injury using his mind to direct a robot to pick up objects and place them on a platform while electrodes stimulated sensory regions of his brain. The feedback made him feel as if he were touching the objects with his own palm and fingers. It also allowed him to complete each movement cycle twice as fast as he could without it.

But this is a long way from visions in which memories are implanted or skills like kung fu are instantly downloaded, says Juan Alvaro Gallego at Imperial College London. "Remembering the texture of the muffin that you ate for breakfast when you were a kid is different from feeling that someone is rubbing your thumb," he says. "We don't know how to write memories or knowledge into the brain."

Moreover, experimental BCIs don't allow for the rapid switching between disparate activities that occupy most people's days: typing one minute, chatting to a friend, then going to the kitchen for a snack. "We cannot build a model that works across all these things that we can do in our daily living," says Gallego.

As a step in that direction, he and his colleagues have found a way to make programming the individual tasks easier. BCIs are currently personalised for each participant, but Gallego's team has created a universal decoder that works across different brains, at least in monkeys and mice. It does this by tracking patterns that emerge in groups of neurons that are shared across a species. "You can build a model in animal 1 to predict how animal 1 is moving his hand, for example, and use it in animal 2," he says. If the algorithm also works across different human brains, it could pave the way to more versatile BCIs, he says.

Advances like these continue to close the gulf between our mental worlds and the neural activity from which these worlds emerge. Yet many BCI experts dare only to dream as far as fashioning these devices into a standard treatment for movement and speech limitations. "We could have therapies for people in a much sooner time frame than I ever thought," says Henderson.

Along with similar firms such as Synchron and Blackrock Neurotech (which produces the Utah array), Neuralink is often seen as a partner in that goal – even if researchers can't yet see a clear path, or rationale, for that company's aim of creating cyborgs who can keep pace with superintelligent AIs. Neuralink didn't respond to requests for comment. "We are still struggling to match the function [of non-disabled people]," says Vargas-Irwin. "We're not at the point yet where we can think about enhancement." ▮

Ingrid Wickelgren is a freelance journalist based in New Jersey

The back pages

Puzzles
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***Almost* the last word**
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Twisteddoodles for *New Scientist*
Picturing the lighter side of life p48

Stargazing at home

A lovely shower

It is nearly time for one of astronomy's dazzling annual sights – the Perseid meteor shower. This year is a bit special, says **Abigail Beall**

Abigail Beall is a features editor at *New Scientist* and author of *The Art of Urban Astronomy*. Follow her @abbybeall

ONE of the highlights of the astronomical calendar, and something I look forward to every year, is the Perseid meteor shower. This impressive display, which is visible in the northern and parts of the southern hemisphere, will peak on the evening of 12 August, running into the early hours of 13 August. What makes it special is that, at least where I am in the northern hemisphere, it tends to happen on a warm evening – unlike the equally spectacular Geminids in December.

The number of meteors you can expect to see during the Perseids varies depending on light pollution, cloud cover and moonlight – but luckily this year, the moon will be in its first quarter on the evening of 12 August. It will set around midnight, giving viewers plenty of moon-free meteor spotting time.

Regardless of where you are in the world, after midnight local time is the best time to look for the meteor shower. Keep an eye on the cloud cover forecasts on the evenings before and after the peak and pick a night that looks best for you to watch it, but you have a better chance of seeing meteors before the peak than after.

Meteors, or shooting stars, are bright flashes of light that quickly cross the night sky. They are caused by pieces of dust and debris entering Earth's atmosphere and burning up. Meteor showers happen when Earth's orbit around the sun takes us through a cloud of dust and debris left behind by a comet or asteroid. The Perseids are caused by remnants of the comet Swift-Tuttle.

FRANK SUN/ALAMY

Meteor showers are named after the constellation the meteors appear to come from in the sky. In this case, it is the constellation Perseus, one of the biggest in the night sky.

You don't have to be able to find Perseus to enjoy the meteor shower, since the shooting stars will cross the sky in all directions. But if you do want to find it, you can do so using the constellations Cassiopeia and Taurus.

Find the bright W or M shape of Cassiopeia, which should be in the north, then follow the imaginary arrow created by the shallower of the two Vs. You should eventually see a small collection of stars that looks like a miniature version of the Plough or the Big Dipper. This is the Pleiades star cluster in Taurus. Perseus sits between the two.

The only thing you have to do now is to make yourself really comfortable and warm. Go somewhere away from light pollution if you can, and, if not, try to turn off any immediate sources of light near you. Let your eyes adjust for at least 15 minutes, lie back and wait for the meteors to appear.

During the peak, you can expect up to 100 meteors in an hour, particularly if the moon has set and you have a clear sky. No matter how often you have seen the shower, it never fails to delight. ▮

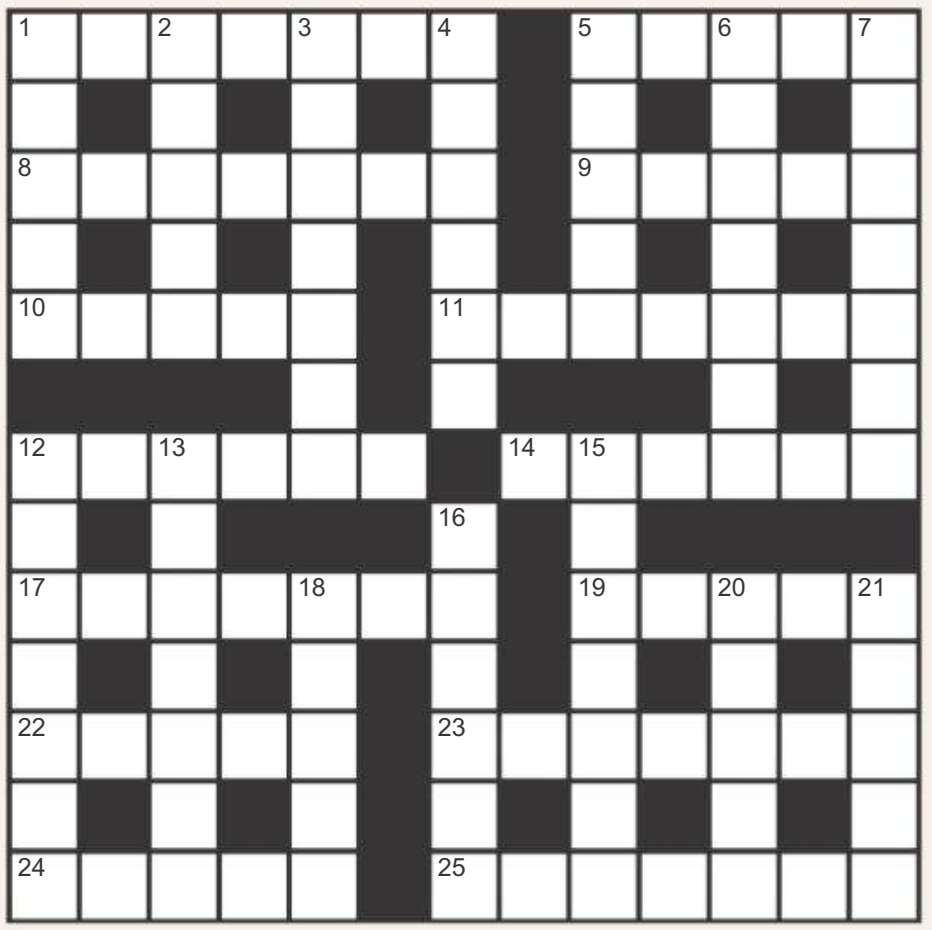
Stargazing at home appears every four weeks. Share your stargazing successes with us on X and Instagram @newscientist using the hashtag #NewScientistStargazing

These articles are posted each week at newscientist.com/maker

Next week

Mathematics of life

Cryptic crossword #141 *Set by Trurl*



Scribble zone

Answers and the next quick crossword next week

ACROSS

1 Particular sort of marine vessel hit quays, it's reported (7)
5 Very junior and very senior journalists raised to power (5)
8 Futurist who wrote *Mercury Springs* (1,1,5)
9 Two accounts from Newton, perhaps (5)
10 After a long wait, incomplete states may have been drawn here (5)
11 Hobble unsteadily after watching third of old horror movie (3,4)
12 Indian material made of three metals (6)
14 Is dishonest bachelor about to make brave descent? (6)
17 Test 50 per cent of people, for instance (7)
19 It's said to be about "battleships": might it be idly contemplated? (5)
22 At home, door opening – former partner's pointing finger! (5)
23 Australian animal cruelly chained (7)
24 UK prime minister, or a lesser official? (5)
25 Memory (a bit) provides protection (7)

DOWN

1 Frisch was swallowing part of speech (5)
2 Energy stored in dish, for part of nutrient processing system (5)
3 Harness fire, we're told, to get enriched content of shell (4,3)
4 Taser broken? Zap leader with substitute (6)
5 Sound as a bell! (5)
6 Reformed liberal writing for people whose views are limited (7)
7 In last month, tells lies about someone stripped in unit (7)
12 Metal sort of music, including acoustic emission (7)
13 Extra 24 hours seen in diary, oddly, after spring (4,3)
15 Utilitarian's crooked – a bad actor (7)
16 Remote, shimmering heavenly body (6)
18 Standard fare is about 9, for animators (5)
20 Spirit of Russia held back by bleak Dovlatov (5)
21 Smallest Tesla carrying most of lead (5)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #263
set by Bethan Ackerley

1 Which galaxy supercluster's name means "immense heaven" in Hawaiian?

2 In what year was the Miller–Urey experiment conducted, aiming to simulate conditions of early Earth?

3 What name is given to the units making up an insect's compound eyes?

4 Which of the following hominin fossils is thought to be the oldest: Toumaï, Lucy or Ardi?

5 Subatomic particles with an equal number of quarks and antiquarks are known as what?

Answers on page 47

BrainTwister
set by Katie Steckles
#31 Fold and cut

Imagine a piece of paper in a portrait (or vertical) orientation. If you want to make this puzzle more challenging, this imaginary piece of paper is all you need, otherwise, you can always try with a real one.

If you fold the paper in half twice (first down, then across), and then cut a small piece off each corner, how many holes will you make through the paper?

What about if you make three folds (down, then across, then down) before snipping the corners off? How many holes now?

Is there a connection between the number of folds and the number of holes?

Solution next week

Time for bed

Why do some flowers close up at night but others stay open?

Leslie Wilson
Reading, Berkshire, UK
The timing of the opening of flowers often relates to the pollinators they hope to attract.

Bees and hoverflies largely go to bed early, in my garden at least. However, some flowers are set up to attract night-flying moths. They are often pale in colour and if I stroll in the garden at twilight, I see that they look more noticeable at that time of day.

In particular, I am thinking about dame's violet or night-scented stocks, both of which release scent at night but give off very little of it in the daytime. I often see moths at these flowers. Evening primroses only open at dusk, and are similarly attractive to moths. They have a luminescent quality in the half dark.

Roses don't shut at night, but they tend to produce the most scent in warm sunlight when bees are most active. I have recently noticed that cultivated water lilies not only close at night but also prefer not to open on dull days.

"Giant water lily flowers close in the morning, trapping pollinators inside, then release them in the evening"

Heather Whitney
Reader in plant interactions, University of Bristol, UK
There are several reasons why flowers are thought to close at night. One is to protect nectar from nighttime thieves, and potentially to keep the rest of the floral tissue safer from florivores. Another reason could be to prevent pollen from getting wet, due to rain or dew forming on the petals.

Closing petals at night also helps to control the temperature, keeping the pollen, stigma and overall flower warmer. Insect pollinators prefer warmer flowers.

There are also flowers that open at night rather than during the day. A classic example is the giant water lily, which opens in the evening and actively warms itself up to attract pollinating beetles. It then closes in the morning, trapping its pollinators inside before releasing them, covered in pollen, the following evening.

Guy Cox
Sydney, Australia
Plants have different pollination strategies. Many are pollinated by bees, which are active by day. Others are pollinated by moths, which are mostly active at night. In fact, some flowers only open at night.

However, some flowers have adapted so that they don't need to expend energy in opening and closing. Many moth-pollinated flowers remain open all the time, but only produce their perfume by night, which can make a summer evening pretty magical.

SHUTTERSTOCK/DUNCAN ANDISON

This week's new questions

Going down **Cycling on hilly roads, what is the best option to save energy: go as fast as possible downhill to gain momentum for the next climb, or stop pedalling to have a rest and regain some strength?** ***Jean-Luc Kerdelhué****, Nantes, France*

Is it easier to cycle uphill if you have rested on the previous downhill slope, or pedalled fast?

Lighting up **Is it feasible to start a fire with a fart and a static spark from human hair?** ***Jed Stephens****, via email*

Tick tock

How do you check the accuracy of an atomic clock that "will lose less than 1 second every 40 billion years", as per a recent *New Scientist* article?

Pat French
Longdon-upon-Tern, Shropshire, UK
Atomic clocks are based upon quartz crystals. These crystals vibrate at a very uniform rate when an electric current is passed through them. By measuring minute variations in those vibrations over months or years, scientists can predict a clock's accuracy.

The value of those variations is so small that it needs to be projected over tens of billions of years in order to be stated in seconds for the benefit of us readers. One second in 40 billion years is a little more meaningful to most of us than 25 picoseconds per year.

Shimon Kolkowitz
Herst Chair Associate Professor of Physics, University of California, Berkeley, US
No clock made by humans can tick for 40 billion years. After all, the universe is a "mere" 14 billion years old so far.

The statement that an atomic clock is so accurate that it can tick for 40 billion years without losing a second is a mathematical metaphor intended to convey just how accurate these clocks really are, using a timescale we are familiar with: the second.

The clock in question has been characterised to have an accuracy of 8 parts in 10^{19}. This is roughly the same as the ratio of 1 second to the number of seconds in 40 billion years (~1.26×10^{18} seconds). There are also ~1.26×10^{18} nanoseconds in 40 years, so it would be equally meaningful to say that the clock could tick for 40 years without losing a nanosecond, or that it could tick for an hour without losing more than roughly 3 femtoseconds (there are 10^{15} femtoseconds in 1 second). These statements are all equivalent.

The ideal way to check if a clock really is this accurate is to compare it to an even more accurate clock, but as no such clock exists, you instead need two independent clocks. After building them, you

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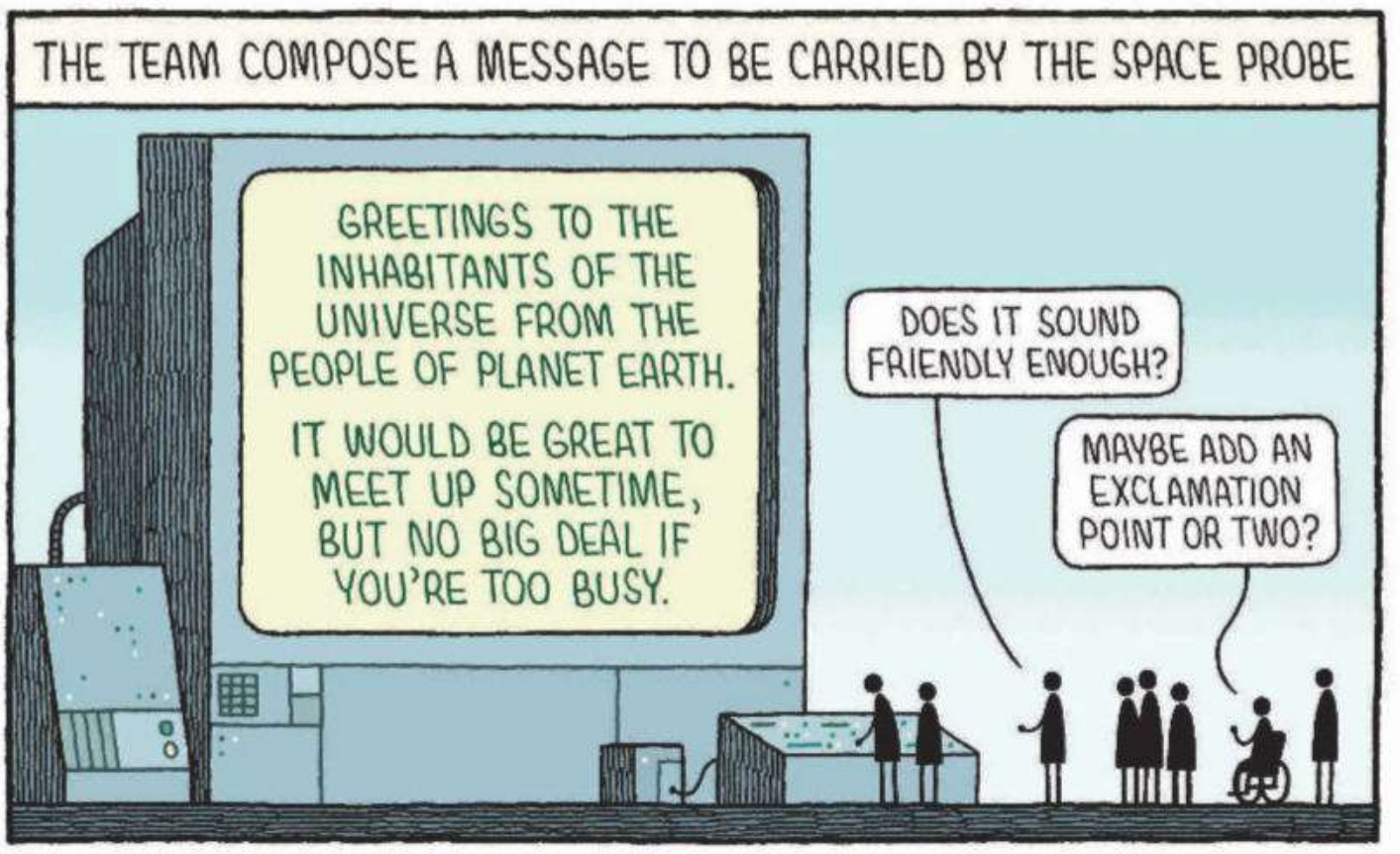
Tom Gauld
for New Scientist


THE TEAM COMPOSE A MESSAGE TO BE CARRIED BY THE SPACE PROBE
GREETINGS TO THE INHABITANTS OF THE UNIVERSE FROM THE PEOPLE OF PLANET EARTH.
IT WOULD BE GREAT TO MEET UP SOMETIME, BUT NO BIG DEAL IF YOU'RE TOO BUSY.
DOES IT SOUND FRIENDLY ENOUGH?
MAYBE ADD AN EXCLAMATION POINT OR TWO?

would compare them to each other over the course of hours or days. If after 1 hour of ticking independently the two clocks still agree with each other on the elapsed time to better than 3 femtoseconds, then they have the claimed accuracy of 8 parts in 10^{19}, and you could argue that if they did tick for 40 billion years straight they would agree with each other to within 1 second.

Going nuclear

Is there a minimum size for an atomic bomb? Would it be possible to make a microscopic one that results in a very small explosion? (continued)

Richard Glover
London, UK
While there is a minimum size for a fission bomb to sustain a chain reaction, there should be no such limit on a matter-antimatter weapon.

For every particle of matter, there is an antimatter equivalent

"No clock made by humans can tick for 40 billion years. After all, the universe is a 'mere' 14 billion years old so far"

identical in every respect, but with an opposite charge. When these two types of matter come into contact, they destroy each other, releasing energy.

In fission and hydrogen bombs, only some of the material is converted into energy, which tends to limit their destructive power. However, in a matter-antimatter weapon, when equal amounts of these types of matter are combined, this should result in their complete conversion into energy. This shouldn't only result in a greater yield of energy compared with a conventional atomic bomb, but it also doesn't have a minimum size limit.

As yet, matter-antimatter weapons are confined to science fiction because of the difficulty of producing antimatter in sufficient quantities.

Combining matter and antimatter would also make a very efficient spaceship propulsion system, even better than hydrogen fusion. This kind of propulsion would enable space travel at sizable fractions of the speed of light.

John Mills
Ben Lomond, California, US
Microscopic atomic bombs do exist. They are created inside nuclear reactors when some of the fuel becomes supercharged with energy, These atoms are the unstable even-numbered isotopes of uranium, plutonium and curium and they explode with the force of atom bombs on a one-atom scale. This is called spontaneous fission and it is the reason why nuclear reactor waste is especially dangerous.

For example, 30 nanograms (billionths of a gram) of this stuff can increase the internal rate of spontaneous fission in your body by a factor of 100, and that isn't good. ▮

Answers

Quick quiz #263 *Answers*

1 Laniakea
2 1952
3 Ommatidia
4 Toumaï
5 Mesons

Quick crossword #163 *Answers*

ACROSS 1 Pectin, **4** Paraffin, **9** In rut, **10** Tyre tread, **11** Ceps, **12** Iron, **15** Raccoon, **16** Lobe, **19** Mako, **20** Oil palm, **23** Proof, **24** Ants, **25** Ball, **27** Dot matrix, **28** Polyp, **29** Permease, **30** Pollux

DOWN 1 Poincare, **2** Carapace, **3** Iota, **5** Adrenal cortex, **6** Automobile, **7/13** Fields medal, **8** Nodule, **10** Tyrannosaurus, **14** Solar flare, **17** Parallel, **18** Smallpox, **21** Sped up, **22** Doctor, **26** Up to

#30 Digital targets *Solution*

The optimal set of numbers is 1, 2, 3, 4, 5, 0, 0, 0, 0 and 0. This gets 150 points.

The digits 0, 1, 1, 2, 3, 4, 5, 9, 9 and 9 can be arranged several ways to get a score of 100 – for example, as 14, 19, 29, 39 and 50.

The highest possible score with the digits 0-9 is 95. There are many ways to arrange this – for example: 19, 28, 37, 46 and 50.

Diet of worms?

The phrase "diet of worms" intrigues people (if it intrigues them at all) in various ways. For historians, it can trigger arguments about a political convocation that happened in the city of Worms, in Germany in the year 1521. For nutritionists, the phrase can describe the work of scientists who are considering whether all of today's 8 billion or so humans could, if need be, subsist on a diet of mainly earthworms.

Henry Miller, James Mulhall, Lou Aino Pfau, Rachel Palm and David Denkenberger, whom Feedback regards as the all-star team of the nutritional-diet-of-worms community, recently feasted on a mass of data. Postprandially, intellectually speaking, they produced a study called "Can foraging for earthworms significantly reduce global famine in a catastrophe?" It appears in the journal *Biomass*.

The five analysed four techniques for efficiently fishing, so to speak, for earthworms: "digging and sorting, vermifuge application, worm grunting, and electroshocking".

They asked the "can" (of worms) question: Can the worms gathered by these methods feed all of us humans, given the constraints of "scalability, climate-related barriers to foraging, and pre-consumption processing requirements"? Their answer, in a word: no.

Their answer in 48 words: "The authors are not aware of any studies of the human health impacts of consuming a diet rich in foraged earthworms. However, in the authors' opinion, there is reasonable evidence that such a diet could be harmful and so should not be recommended unless starvation is the alternative."

Diets of worms

Miller, Mulhall, Pfau, Palm and Denkenberger are but the most recent front-runners in a long parade of scientists drawn to investigate diets of worms.

Many others have focused on the diets of the worms themselves.

Charles Darwin attained some measure of his fame for the 1881 book *The Formation of Vegetable Mould Through the Action of Worms*. Nearly a century later, Kristian Fauchald and Peter Jumars's "The diet of worms: A study of polychaete feeding guilds" occupied 92 pages of the *Oceanography and Marine Biology Annual Review*.

Fauchald and Jumars included a conversation-stopper of a sentence that is worth memorising and spouting if you want to worm your way into the spotlight at a party: "Alciopids are holoplanktonic animals with muscular, eversible pharynges."

Other scientists studied what can happen when one eats worms, especially if one isn't a human.

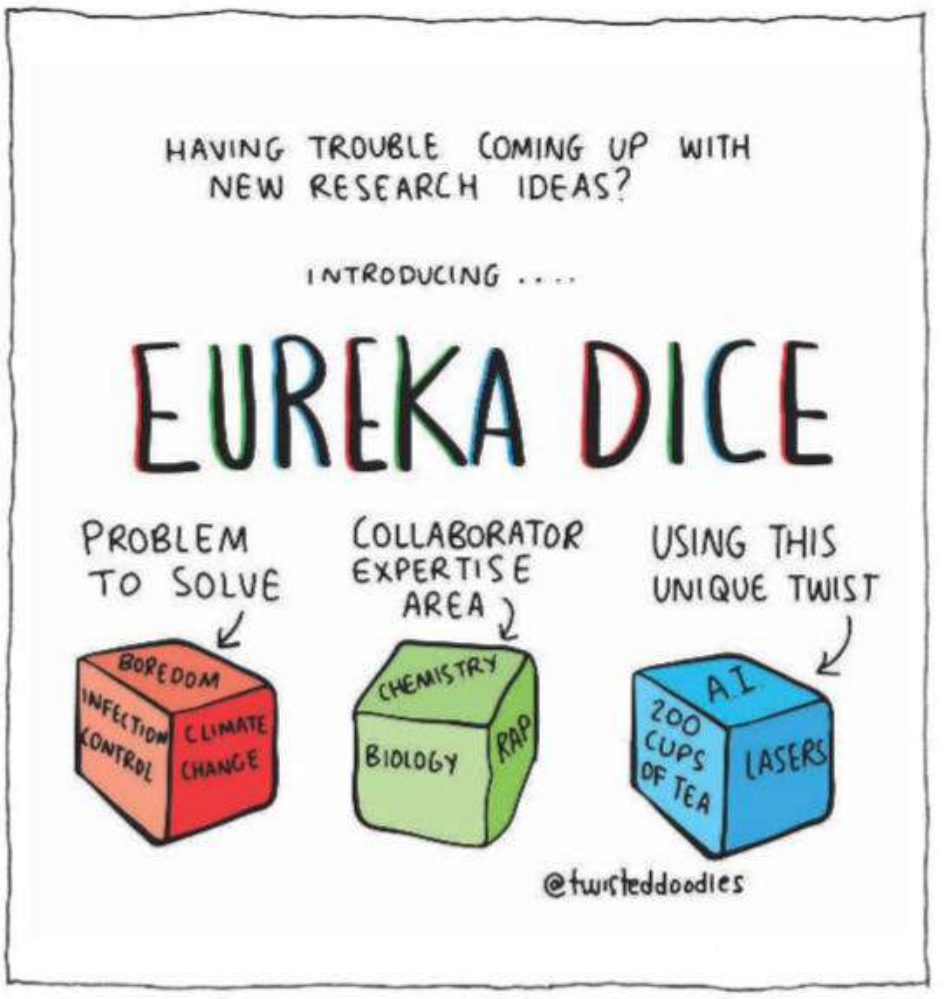
In 2002, Mary Silcox and Mark Teaford examined the teeth of some habitual worm-eaters. They wrote up their observations, for the *Journal of Mammalogy*, under the title "The diet of worms: An analysis of mole dental microwear".

"We compared microwear from shearing facets of lower molars from *Parascalops breweri* (the hairy-tailed mole) and *Scapanus orarius* (the coast mole) with that from other small mammal species including a tenrec, a hedgehog, 3 primates, and 2 bats."

Some of the mole tooth wear patterns, they write, can be "plausibly explained by the interaction between teeth and soil from the inside and outside of earthworms".

Silcox and Teaford's mole teeth research would take on new significance if and when – despite the warning given by Miller et al. – the peoples of Earth opt for a mostly earthworms dietary regimen.

Twisteddoodles *for New Scientist*



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Consideration of items sent in the post will be delayed

The tall and short of it

News about height requirements for certain courses at Vietnam National University's school of management and business (HSB) has Feedback wondering.

***Deutsche Welle* reported on 2 July that "female students must be at least 1.58 meters tall and male students at least 1.65 meters to be considered for admission this year". The reasoning here: "the school aims to train future leaders and excellent managers" and "height is a decisive factor, especially when it comes to leadership and self-confidence".**

That news report says that after public outcry, "HSB adjusted its admission criteria" so that "the rule now applies only to one course, Management and Security".

What schools or other institutions in the science, medical or tech world have managed to secure strict height prohibitions for students or employees? If you know of one, please send documentation to Feedback with the subject line "Big/Small Careers". Some job requirements sensibly specify that applicants be physically able to use some particular job-related equipment. Don't send those. Feedback craves examples in which numbers, not needs, rule the day.

Toilet humour

Inspired by Feedback's collection of abandoned organisational slogans, Ken Taylor takes note of a slogan about things that were abandoned.

"I live in a very rural part of [the] UK – Cumbria. There are lots of isolated properties that are not linked to the sewerage network, so rely on septic tanks. These have to be emptied from time to time. I saw one such tanker going about its business. The slogan on the side said 'Yesterday's meals on wheels'. Nothing more to add..." ▮

Marc Abrahams

Discovery Tours

NewScientist

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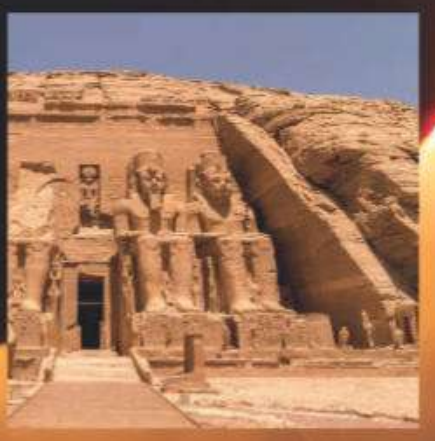

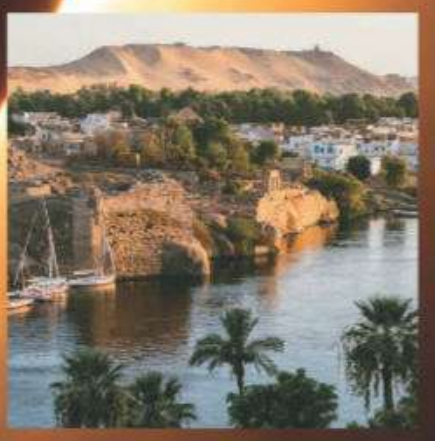

Total solar eclipse 2026: Iceland to Greenland polar cruise

7 August 2026 | 13 days

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You will be accompanied throughout by guest speakers, including astronomer and eclipse expert Jamie Carter, who will guide you through the event with talks and workshops on solar photography and astronomy.

- **Explore the majestic Scoresby Sund in Greenland, the world's longest fjord system.**
- **Encounter a fascinating variety of species, including barnacle geese, musk oxen, Arctic foxes, Atlantic puffins and walruses.**
- **Led by a highly knowledgeable and supportive expedition team, who will give a full programme of talks, shore visits and Zodiac boat safaris.**
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- **Explore Iceland's Golden Triangle, including Þingvellir National Park and the Geyser geothermal area.**

Total Solar Eclipse 2027: Nile cruise, Egypt

27 July 2027 | 10 days

Marvel at the longest solar eclipse over land this century, positioned close to the central line of totality in Luxor. Travel aboard the MS Nile Premium sailing along the historic Nile River from Aswan to Luxor, surrounded by the timeless beauty of Egypt's ancient landmarks.

Accompanied by an eclipse expert and *New Scientist* US editor Chelsea Whyte, who will give talks on eclipses, astronomy, cosmology and how these intersect with Egyptian archaeological history expert-guided excursions to some of the most iconic sites in Egypt during the trip.

- **Experience an awe-inspiring celestial spectacle from the luxurious comfort of an elegant river cruise ship.**
- **Spend 10 days aboard the MS Nile Premium from Aswan to Luxor, your home for this enchanting Nile cruise.**
- **Explore several amazing archaeological sites in small groups led by Egyptology leaders, including the Valley of the Kings, Karnak Temple, the Temple of Luxor, the Temple of Edfu, Philae Temple, the Tomb of Nefertari and Abu Simbel.**
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